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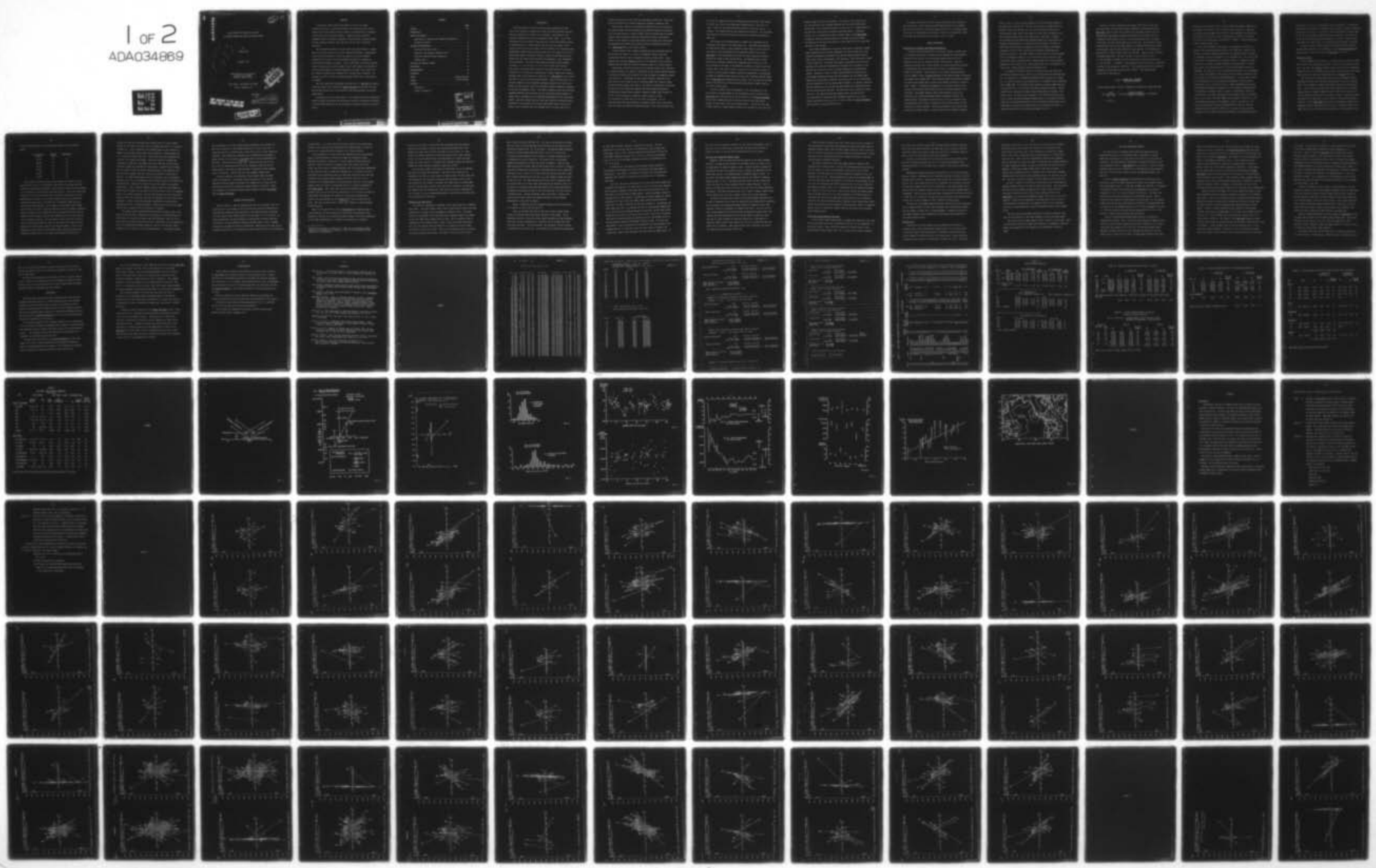

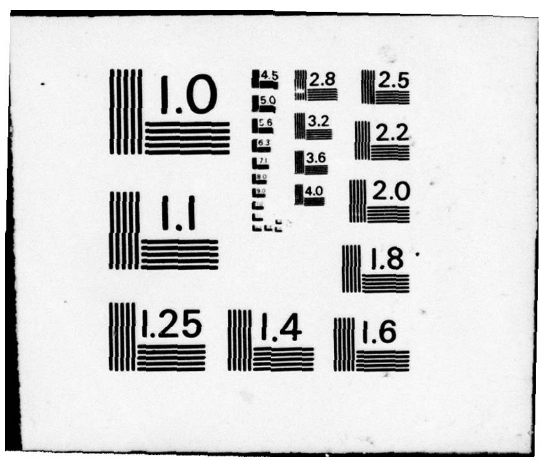
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GEOID HEIGHTS AND GEODETIC POSITIONS OF PACIFIC HARBORS AND DEEP SEA DRILLING SITES

by

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ABSTRACT

A relatively simple double pass method is used to (a) reduce longitudinal spread of satellite navigation fixes and (b) obtain antenna height or sea level height on board a ship in a fixed harbor or fixed open-sea position (over an acoustic beacon). Required are the satellite navigator output of latitude, longitude, elevation angle, and path geometry for two consecutive passes (one E and one W of the site) of the same satellite.

The standard deviation of one such double pass observation in a larger data set is usually below 20 m in both longitude and height. Improvements in the position accuracy of a site (as measured by σ_m, the standard deviation of the mean or the 95% confidence interval) are obtained by restricting observations to passes: with a high number of symmetric Doppler counts, between given elevation angles, with a small number of iterations of the satellite navigator, and with eliminations of double pass results that are outside specified limits (usually 2σ) in height and/or longitude. An accuracy σ_m of 10 m or less is usually achieved within four to five days of recordings.

Sea level height thus determined on Board the R. V. Kana Keoki in harbors around the Pacific and on board the Glomar Challenger in position over Deep Sea Drilling Project sites in the Atlantic show good agreement with geoidal height models.

Determining sea level (with respect to the Navigation Satellite Reference) using the double pass method thus provides an important independent alternative to Sky Lab Radar Altimetry for the measurement of geoidal height over the open oceans.

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INTRODUCTION

The Navy Navigation Satellite System became operational in 1964. Since then, commercial equipment has become available with which position fixes in longitude and latitude can be obtained. Descriptions of the satellite system have been given by Stansell (1970, 1976). In the 1976 description an error budget is presented (on p. 481) for different sources of uncertainties at a fixed location, and the "root sum square" of the errors is given to be in the range of 18 to 35 meters for "laboratory type" measurements, whereas field results usually lie in the range of 27 to 37 m. These values apply, according to Stansell, after the time when the polar motion error was modeled and included as an adjustment to the transmitted orbit parameters. The errors found during the present study (standard deviation, σ) are about 20 m or less in both height and longitude when results of two consecutive passes of the same satellite in the same direction (N- or S-bound) are combined into a simple "double pass" solution obtained from a fixed position on board the R. V. *Kana Keoki* when the vessel was tied to a pier in various Pacific harbors. Berg (1975) has shown in a detailed example that the longitude positions obtained by the double pass method are more accurate than those obtained by simple arithmetic averaging, as was done by Daugherty (1974). The simple arithmetic means show increased standard deviation with increased error in initialized antenna height, an effect that is eliminated in the longitude determination by the double pass method. Some very limited data for fixed land stations in Colombia during spring 1973, also analyzed by the double pass method (Berg, 1975, and in press), seem to indicate that the standard error is of the order of 9 m,

without application of corrections for tropospheric refraction. These data also were obtained with standard commercial equipment (a Magnavox 706).

The writer's interest in the problem of SAT NAV fixes, and especially the antenna height correction problem, was generated through his participation in Project Nariño, a seismic crustal study in Colombia that was depending upon satellite-defined positions reported by Woollard and Thompson (1974) for the location of land shot points and recording sites that would be compatible with offshore shot points obtained by SAT NAV on board the R. V. Kana Keoki (Berg, 1975, and in press).

For the present study, computer programs have been developed with the aid of Duncan M. Chesley to replace the graphical solutions and hand calculations that were used to prepare the report of Berg (1975). These programs allow various selection criteria to be applied to the raw data as obtained directly from the satellite navigator output at a fixed location.

Among these selection criteria are the elevation angle of the satellite at closest approach, the number of iterations of the internal SAT NAV computer to obtain the latitude and longitude fix, and the number of symmetric Doppler count intervals. In addition to these direct criteria, selection from a given data set can be made by day or satellite number and "erratic" values rejected from the double pass results. The latter is achieved by calculating the mean values of height and longitude and their standard deviations, eliminating all double passes outside a specified height limit (usually 2σ or 3σ), then eliminating, in addition, double passes for which the longitude is outside the 2σ or 3σ limit in longitude. For the remaining passes the same procedure is repeated as many times as necessary until no values are outside the specified limits. This last procedure works

very well for larger data sets but sometimes misses obviously "bad" values for small sets (five to ten double pass determinations), even with a 2σ limit. Results of each such interaction step are printed out by the computer. Two output plots are also obtained for each site: (a) all double pass solutions and (b) the retained solutions (if different from the set under (a)).

The accuracy of the position data in height (and longitude) will be discussed on the basis of the larger data sets. The height determinations are particularly useful, since no geoidal height changes (of the order of the accuracy of the determination) are expected between visits of the *Kana Keoki* to the same Pacific ports over the years (especially Honolulu, abbreviated to HNL or HON, and Suva Fiji). No comparison will be made between the determined latitudes and longitudes and the position of the ship (antenna) on the maps of the different locations, as had been done for Colombia (Berg, 1975, and in press), since this is the specific subject of a thesis by Valerie Hanna of Hawaii Institute of Geophysics, who graciously provided the IBM data cards with the raw data (the individual SAT NAV fixes) for all *Kana Keoki* data prepared for her thesis. She also prepared the data cards for SAT NAV fixes of the Deep Sea Drilling Project (DSDP) sites for use in the present study.

The other result of this investigation is the determination of sea level height or geoidal height at the circumpacific ports visited by the *Kana Keoki* and in the open sea at the drill sites of the *Glomar Challenger*. On the earlier DSDP sites only a few fixes had been taken and geoidal heights are known there with only limited accuracy. During the later part of 1974, however, a larger number of passes were recorded at each site, and

geoidal heights are better determined. The accuracy varies from site to site (as measured by the standard deviation (σ) of a single double pass observation). This variation from site to site is due to residual motion of the ship over the drilling site between satellite passes. In general, however, the σ's obtained are similar to those found on board Kana Keoki in harbors, and the standard deviations of the mean (σ_m) of the height determination at the open-ocean sites is of the order of 12 m or less, with some near 2 and 5 meters.

This height determination at open-sea sites gives an important "ground truth" measurement with accuracy comparable to or better than that of the (limited) determinations obtained by the Sky Lab Radar Altimetry during a single orbit (Leitao and McGoogan, 1974; King-Hele, 1976) and seems to permit a direct comparison. Since many more passes and different satellites are involved in the open-sea determinations presented here as compared to the observations of Sky Lab, errors of orbital parameters are considerably reduced. King-Hele's Figure 9 (1976) shows differences between the sea level height determined from the Sky Lab altimeter and the Goddard Space Flight Center Earth Model 8 (GEM 8) of the order of 20 m, west of Australia and also southeast of the Izu trench (SSE of Honshu). It appears, therefore, that the method used here provides geoidal heights from existing data that had not been previously utilized. The method can also be applied to future data sets. The data presented here suggest that a two-day position recording from all operational Navy navigation satellites can yield a height determination with σ_m of 5 m or less on board the Glomar Challenger when located in a fixed position at sea.

No height corrections for earth or ocean tides have been included in the calculations. Their inclusion could further reduce the σ in harbors where the ocean tides are relatively large (such as 3 to 5 m along portions of the coast of South America), and where σ seems to be larger than in HNL where tides are usually only of the order of .6 or .5 meter.

DOUBLE PASS METHOD

Application to longitude and height determination

In this section the method will be reviewed. During a specific pass of a navigation satellite, the Doppler counts obtained are predominantly a function of the position of the receiving antenna along the line of satellite motion and its distance from the orbital plane. Since the navigation satellites are in polar orbits, the along-track position relates to latitude and the cross-track distance relates to longitude and the height of the antenna. Since distance is one of the factors determined from the Doppler counts, a priori knowledge of the antenna height is necessary to determine the longitude fix. Both "antenna height" and "satellite height" are taken as the height above or below the reference ellipsoid or satellite datum. Figure 1 illustrates the geometry of two satellite passes in the vertical, E-W oriented (cross-track) plane at the closest approach of the satellites. The figure indicates that erroneous fixes L_1 and L_2 are obtained if the initialized antenna height is different from the true antenna height. The amount of the fix error L_1-L or L_2-L depends on the initialization error dH and is a function of the elevation angle k of the satellite at closest approach. For the calculations in this report, this function of elevation angle k: f(k) was taken from the graph in Stansell

(1976, p. 486). It was carefully measured at the 10°-intervals marked in the graph and at 65° and 75°. The ratio of fix error to height error (in Stansell, 1976) was converted to a fix error (in nautical miles) per m antenna height error, which is the same as the fix error in minutes of arc per m antenna height error at the equator and is then f(k). A smooth curve through the data points thus obtained yielded the other values at 1° elevation angle intervals. The nautical mile was taken to be 1853.2 m. Since fixes of the satellite navigator are given in degrees and minutes, conversion of the fix error (to m) can be obtained by multiplying the $dL_i(=L_i-L)$ by 1853.2 • cos (LAT), where the units of dL are taken in minutes of arc. Returning to Figure 1, it is seen that if f(k) is the fix error (in nautical miles) resulting from a 1-meter height error, then a dH-meter height error will result in dH • f(k) nautical mile error in longitude or an error of dH • f(k)/cos(LAT) in units of minutes of arc.

If a number of satellite passes are recorded at the same fixed site, each having elevation angle k_i and fix L_i and data points for satellite pass No. i are plotted in a rectangular coordinate system at points $Y_i = f(k_i)$, $X_i = L_i$, then the points Y_i, X_i ideally fall on a straight line for which the slope is $\frac{dy}{dx} = \frac{1}{dH}$; or the inverse slope giving the antenna height error and the value for L at y = 0 will give the correct longitude position. This is essentially the approach to obtain a three-dimensional fix (Anderle, 1971; Greely, 1971). As can be seen from Figure 1, the direction from the true fix (L) toward the SAT NAV computed longitude (L_1) is the opposite from the direction of the passing satellite if the initialized antenna height is too high (that is toward the W (position L_1) for an E-passing satellite), or toward the satellite if the initialized height is too low.

However, the writer previously found (Berg, 1975, and in press) that with operational receivers under field conditions in Colombia and on board Kana Keoki, better results (less spread in the longitude position fix) are obtained when the height correction and longitude fix are taken only for individual "double passes", that is, for the same satellite at two consecutive orbits, one east and the other west of the site. For the final fix and height the mean of all such double passes for longitude and height are taken. As an example, take the first satellite double pass (No. 67) in Table 1A, B HNL site No. 25, that is pass 3 and 4 (on day 307). (Refer to Fig. 2 for the following discussion.) The first one (No. 3) was E of the site at a $K = 18^{\circ}$ ($f(18^{\circ}E) = 0.000381$), and the second (No. 4) was W of the site at a $K = 31^{\circ}$ ($f(31^{\circ}W) = -0.000512$). The longitude of the first one was $-157^{\circ}52.023'$ and that of the second was $-157^{\circ}52.033'$. The latitude for both (to sufficient accuracy for the height correction) was $21^{\circ}18.8'$. The antenna height correction is then given by

$$dH(m) = \frac{dx(\text{min arc}) \cdot \cos(\text{LAT})}{dy(\text{nautical mile/m})}$$

(since nautical miles = min arc • COS(LAT)); the numerical values thus give

$$dH = \frac{L_1-L_2}{f(k_1)-f(k_2)} \cdot \cos\ (\text{LAT}) = \frac{-52.023-(-52.033)}{0.000381-(-0.000512)} \cdot \cos(21^{\circ}18.8')$$

$$= +\ 10.43\ \text{m}.$$

Adding the correction dH = 10.43 m to the initialized antenna height (23 m) then yields the ANT HT of 33.43 m listed in Table 1B (pair 1). Since the initialized antenna height was too low the true longitude is W of the first fix (L_1) and the fix error is $dH \cdot f(k_1)/\cos(LAT) = 0.0042'$, so that the true fix for this double pass is $157^o52.023' + 0.0042' = 157^o52.0272'$W (also listed in Table 1B (pair 1)).

In the actual computer output plots, in the Appendix as well as in Figure 2, the increasing absolute value of the longitude is always in the positive x direction; E-passing satellites are plotted positive in y(f(k)) if longitude is E and are negative in y if longitude is W. As a result, the slope of the line connecting the two passes in the x, y diagram is always positive for a positive (upward) correction of antenna height. The more near vertical the connecting lines the less antenna height correction is indicated. Note that the x scale is different from plot to plot, depending on the range in longitude of the single pass fixes actually observed at the site and used for the double pass determinations. On each computer output plot of the appendix, the two positions belonging to a double pass are connected by a line. Above the line is a number indicating the satellite identification followed by a letter N or S (if available) indicating that the direction of satellite travel is north- or south-bound. Below the connecting line the number indicates the chronological order of the double pass in a set (that is the pair number in the example of Table 1B and the corresponding output plot in the Appendix, Group I, site HNL 25). All double pass height and longitude determinations are given in separate computer printouts (similar to Table 1A to D) where the mean standard deviation (σ) of a single double pass observation, and standard deviation

of the mean for the set of observations (σ_m) are calculated. If rejection criteria have been applied to eliminate some observations further calculations are executed (see later). The result of these calculations is also printed at the top of the computer output plots of the appendix. The bottom line of the output plots gives general information as to date, location and/or site number, and, after "HT:", the initialized antenna height (in meters).

In order to obtain geoidal height from antenna height the latter's distance above water has to be subtracted. On the *Glomar Challenger* this antenna height is near 22 m and on the *Kana Keoki* it is 18 m.

Selection criteria

As the programs were developed, it was found useful to limit the double pass fixes to those judged most reliable. Two types of criteria have been used: the first type *selects* satellite passes on the basis of information supplied by satellite navigator output, and the second selects those double pass results most consistent among themselves, or *rejects* "bad" ones.

The first type of criteria that have been used throughout involves retaining satellites with elevation angles between 5° and 75°, and their fixes if the navigator's computer calculations show five interactions or fewer. Another option uses only those fixes obtained with a prescribed minimum number of symmetric Doppler counts on each side of the point of closest approach (for HNL site 25 see Table 1B, top). Selection of double pass fixes for a single day or by the satellite identification number is possible. For all *Kana Keoki* data the same identification numbers as in Daugherty (1974) or Berg (1975) have been used. Satellites used for the DSDP site fixes are identified by a two-digit code corresponding to the

third and fourth digits in the Navy satellite number in the following manner:

Navy Satellite Number	DSDP ID Number	Kana Keoki
30 120	12	42
30 140	14	54
30 180	18	63
30 130	13	64
30 190	19	65
30 200	20	99

The rejection criterion relates to the standard deviation (σ) of the double passes in a set of observations, that have been retained after the selection criteria had been applied. Since erratic or bad fixes are obtained, it is desirable to eliminate those from the data set. Rejection of positions outside a 3σ (or 2σ) limit works well on relatively large data sets (> 30 double passes), whereas even a 2σ limit "misses" where just a quick look would subjectively reject one double pass in relatively small data sets (four to ten double passes). As an example, see the output plot of DSDP Site 353 (Fig. 3), where clearly the position at the "0" crossing (longitude) and the inclination of the connection line for satellite 14/5 and 13/4 are different from the others, but were not eliminated by the 2σ limit applied in the rejection criterion. For the purpose of this report the rejection with a prescribed multiple-of-σ limit on both sides of the mean was first applied to the double pass results of the antenna height. If one or more heights were found outside the prescribed limits, the double passes were completely dropped from the list, means and standard deviations were

recalculated and the same process was iterated until no values remained outside the nσ limit of the last step (see example HNL site 25, 2σ iteration in Table 1C). After elimination of all double passes by the iteration on height, the remaining double passes were iterated in a similar manner but as to longitude (example Table 1D). Usually the bad values disappear with the first few iterations on height. After the iteration on height and longitude are completed, only double pass fixes that have survived these rejections remain for calculation of mean height, longitude (and latitude). For the example of HNL site 25 the final mean height, mean longitude, and mean latitude, together with the σ and σ_m, are printed at the bottom of Table 1D. The same values appear on the top portion of the corresponding computer output plot in the Appendix Group I with the bottom line "DAY 306-313 1972 KK HNL HT: +23M #25 2σ", where 25 is the site number (see Appendix, description). From a different example, Figure 4 shows the distribution of height values for HNL site 41A (that is the 1973 portion of site 41) remaining after a 3σ iteration rejection. The four values shown with open circles are those that have been rejected on the basis of subsequent 3σ iterations on the longitudes. Figure 5 shows the longitude distribution of the same site, remaining after the 3σ height iterations. Values shown by open circles again indicate those rejected by the 3σ iteration on longitude.

One might consider proceeding with some kind of absolute limit on the excursion from the mean. Knowing that the accuracy of the NAV SAT system is of the order of a few tens of meters, one could eliminate, say, the two to five values the farthest from the mean (for a larger data set) and additionally reject all height and longitudes outside of, say, 70 m of the mean (after elimination of the first two to five extreme values). It was found, however,

that proceeding on a $n\sigma$ basis allows better recognition of the quality of a data set (as given by σ, the standard deviation of a double pass fix). A reasonably good fix is obtained with σ about 20 m or less in each height and longitude. Since height and longitude are not independently determined, a height accuracy in one usually is associated with a poorer determination in the other. Typical values for $\sqrt{\sigma_H^2 + \sigma_L^2}$ (obtained for HNL site 41) are 26.7 m for 3σ iterations and 12.8 m for 2σ iterations, where of the 130 double passes in the list 117 remained after 3σ iterations and 65 remained after 2σ iterations. Smaller data sets show somewhat larger values.

To avoid confusion, one limitation of the present computer program should be pointed out. If satellite fixes were taken at a site but the initialized antenna height was changed, the program runs as a data set only those fixes for which the initialized antenna height was identical. There were instances of initialized antenna height changes on both the Kana Keoki and the Glomar Challenger.

ACCURACY AND RELIABILITY

Stansell (1976, p. 481) has indicated that the root sum square error of a position fix is in the range of 18 to 35 m when the laboratory standards and sophisticated refraction correction models of the Applied Physics Laboratory are used, whereas field results would lie in the range of 27 to 37 meters. In these measurements, the exact elevation of the antenna is usually known and initialized. In the operational shipboard SAT NAV, however, only a standard troposphere is assumed for the fix calculations. Additional errors that are predominantly reflected in the longitude fix result from the error in the initialized

antenna height. It is this later error that is reduced by the double pass method; at the same time the method yields the antenna height, a result not given by the on-board satellite navigator (for a fixed position).

It was somewhat of a surprise that the shipboard results, using double passes, indicated similar accuracies in height and longitude as those mentioned by Stansell, especially if a larger number of double passes are obtained. With the exception of problem sites (like Callao, Peru) the double pass method gives a standard deviation (for one double pass observation) of less than 20 m both in height and longitude on a 2σ iteration for ten or more double pass observations where all individual fixes have been used from satellites with elevation angles between 5^{o} and 75^{o}, and five or less iterations of the SAT NAV, where no restrictions have been put on the minimum Doppler counts (see Table 2 and Appendix Group I for heights determined on board <u>Kana</u> <u>Keoki</u>). Some "good" sites even yield standard deviations of between 7 and 10 m on a 2σ iteration (KK sites 14, 15, 25, and 41 in Table 2). Since height and longitude are coupled in a double pass determination, however, very good results for one usually lead to poorer results for the other. The root sum square error ($\sqrt{\sigma_L^2 + \sigma_H^2}$, however, is usually between 25 and 30 meters.

Since in the years 1971 to 1974 the <u>Kana</u> <u>Keoki</u> made numerous stops in certain harbors, the actual position in each harbor being different from occasion to occasion, we restricted the tables (Tables 3 and 4*) to comparison of the height determination. It should be mentioned that no (height)

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*Whenever there appears a reference to a table the corresponding computer output plots are found in the appendix. Refer to the description of the appendix for locating data.

corrections for ocean or solid earth tidal variations have been applied. Such variations should not affect the double pass determinations since changes are rather small over the time span of 1 hour 40 min to 1 hour 50 min that elapses between two consecutive passes of the same satellite in the locations considered here, but could affect the σ where the tidal ranges are several meters. In harbors like Anchorage, Alaska with some 10 m changes the tidal variations should be taken into account.

The reason for using 3σ iterations on larger data sets is to eliminate bad values (in height and longitude). Bad values occur sometimes for individual fixes when the total number of Doppler counts is rather small and very asymmetric, the iterations required by the SAT NAV are four or five; but sometimes we were unable to determine any reason based on returned data. The same reasons apply to smaller data sets for 2σ iterations, and even then the computer does not always catch a bad value that could be eliminated by eye or perhaps in a more sophisticated manner by specifying an absolute value of the deviation from the mean.

Variation with time of day

The reason for applying 2σ iterations to the larger data sets is somewhat more subtle. Some more extreme values occur at given (local) times of the day, probably due to changes in the tropospheric refraction index. The author previously found (Berg, 1975) that double pass longitudes showed less spread in the late night-early morning hours for Suva. The 2σ iterations tend to eliminate the more extreme values. Figure 6 shows the height distribution for one of the largest data sets (HNL 41) as a function of time (in GMT); 0 hrs GMT is 14 hrs local in HNL. There is a well-marked trend of a steadily decreasing antenna height between 1 hrs GMT to 7 hrs 30 min and a rather

small variation between 9000 and 1730. The times as given here for a double pass are those of closest approach of the first pass of the satellite; the second pass occurred some 1 hr 46 min later. The antenna height determined from the 46 values between 9000 and 1730 hr is 19.1 m ± 8.4(σ) and ± 1.24(σ_m), which compares to 20.96 ± 8.94(σ) ± 1.11(σ_m) determined by the 2σ iterations on site 41 (Table 4A). The value of 19.1 m is probably somewhat low because of the three low points in Figure 6. The even more time-restricted set between 1300 and 1518 yields 22.90 ± 5.37(σ) ± 1.39(σ_m) m from only 15 double pass observations, indicating that the local night hours from about 3 a.m. to near 7 a.m. (time of the last second pass) give a much more reliable observation and that the σ_m is only slightly larger than that of the total set. The night observations (22.9 m) can be compared to what the writer thinks is the best height determination for Honolulu, that is, a 2σ iteration on heights alone (hand-calculated) which retains 198 from all 248 heights determined from 1972 to 1974 (see Table 4A) of 22.58 ± 13.57(σ) ± 0.96(σ_m) meters. Perhaps taking the ocean tides (about .6 meter) into account would further reduce the standard deviation of early morning observations to less than 5.0 meters.

Figure 7 similarly shows the longitude double pass fix distirubtions as a function of time of day for HNL 41A.

Table 4A (for HNL) and Table 3A (for Suva) further compare height results at different port calls and/or locations in the harbor. The σ_m (standard deviation of the mean) limits usually straddle the best determinations that have been obtained by 2σ iterations (on the height alone) from all heights obtained. To be more precise, the confidence intervals should be determined for each data set. As a function of the number of observations

the 95% (98%) confidence intervals in multiples of σ_m are: for four observations $3.2\sigma_m$ ($4.5\sigma_m$) and for 120 observations $1.98\sigma_m$ ($2.36\sigma_m$) (see Crow et al., 1960, p. 231). The best Honolulu determination of 22.6 m has a 95% (98%) confidence interval of ± 1.9 (2.3) m, and the early morning value of 22.9 m has a 95% (98%) confidence interval (15 observations) of ± 3.0 (3.7) meters.

A different way of looking at this accuracy problem consists of determining the convergence of the mean values with increasing number of observations. This method is illustrated in Figure 8 for the height and longitudes that remained for Honolulu site 41A after the 3σ iterations processing.

The first data point corresponds to the first double pass height (and longitude) determination. The next point (N = 2) is the mean value obtained for the height (longitude) from double pass one and double pass two. The N'th point is the mean after N double passes. Nearly stationary values are obtained after 30 double passes. Oscillations in antenna height are clearly associated with time of day, the higher peaks being associated with the early hours (in GMT) of each day, as they are in Figure 6. In addition, the final values show the $\pm 1\sigma_m$ interval for this 3σ iteration and compare them to (a) the final value obtained through 2σ iterations; (b) the final values obtained for the full set for site 41 for both the 3σ and the 2σ iterations (the other selection criteria are identical) and (c) the heights of the 3σ and 2σ iteration values on all heights obtained for HNL. As can be seen from Figure 8, the 2σ iterations on the different sets give somewhat lower heights than the 3σ iterations, since the former tend to eliminate the consistently higher values observed in the early day time (GMT) hours. In

all cases the 95% confidence intervals ($> 2\sigma_m$) overlap considerably; even if one stops after ten double pass observations (HT about 18 m) the mean is within less than 5 m from the best determined values of 22.6 meters.

Variation with symmetric Doppler counts

Daugherty (1974) has mentioned that the reason for the small standard deviation on longitude and latitude for Wellington (site 15 in Table 2) was the high number of symmetric Doppler counts. We have therefore analyzed in some detail the data for a number of sites to compare the dependence of the double pass results on increasing number of symmetric Doppler counts. In the tables and output graphs (Appendix Group III) the "number of symmetric Doppler Counts" or "D.C. > No" means that there have been more counts both before and after the closest approach than the number indicated. Thus in Table 4B for HNL sites 40 and 41 in the last line under the heading "SYM.CTS." the number "> 10" means that there have been at least 11 Doppler counts before closest approach and at least 11 Doppler counts after closest approach.

In Table 4B for HNL sites 40 and 41 the antenna heights obtained by the 3σ and 2σ iterations on all fixes are compared to those obtained by restricting the observations to progressively higher numbers of symmetric counts (and using the liberal 3σ iterations to eliminate bad fixes). As can be seen in Table 4B and Appendix Group III the height determination becomes better (the standard deviation diminishes) for increasing number of symmetric counts. But even for fixes obtained by using only passes with a high number of symmetric Doppler counts, there remain some (in the 3σ iterations) that one would like to eliminate. Where they actually were eliminated, the results are indicated by an asterisk in Table 4B.

Tables 3B and 4B indicate that little final accuracy (σ_m) is gained by restricting double pass height determinations to those with a high number of symmetric Doppler counts, that the final height values are close to those of the 2σ iterations on all data, and that because of the larger amount of fixes available, the 2σ iterations have smaller standard deviations of the mean (σ_m) and smaller confidence intervals.

It should be pointed out that even highly symmetric Doppler counts sometimes lead to fixes that are off from the remaining data as was the case for one (single fix) with 27 total Doppler counts and 13 after closest approach; elevation angle was 22^o and the satellite navigator did only two iterations for the fix. This questionable fix leads to an antenna height of 118 m for the double pass determination in the HNL 40 set and compares to the 12.7 m for the remaining seven double passes (in the last line of Table 4B) for symmetric Doppler counts > 10. Eliminating this bad height also reduced the σ from 40.3 to 16.7 m, more in line with the accuracy for double passes. That the height value (12.7 m) of this particular set of double passes is lower than the usual 22 m for HNL stems from the bias due to a particular satellite (65) that consistently seems to indicate lower heights (Berg, 1975). Results for additional sites obtained by selecting higher numbers of symmetric Doppler counts are presented in Table 5 and are more extensively discussed under "Problem Sites".

Variations among different satellites

In the earlier report (Berg, 1975), no significant differences were found between the double pass fixes of different satellites for the longitudes. It was noted, however, (Berg, 1975) that satellite 65 always showed a lower antenna height than the other ones. Since in the earlier report longitudes

and heights were obtained graphically and from somewhat different numerical values for the height corrections, the Suva data (sites 13 and 14) have been reexamined together with those for HNL (site 41) where a sufficient number of double passes for individual satellites were available.

As can be seen from Table 3C for Suva (sites 13 and 14) and Table 4C for HNL (site 41) (Appendix Group IV), the σ of a height determination from a specified satellite is of the same order or better as that from all satellites combined.

Combining all heights determined for satellites 42, 54, 63 and 64 and 65, however, a value is obtained (59.5 m) different from that of 65 alone (35.8 m) for Suva sites 13 and 14. Similarly the data for HNL site 41 indicate (Table 4C and Fig. 9) a lower height (10.5 m for 2σ iterations) for satellite 65 than for all satellites combined (21.0 m for 2σ iterations). This lower height also is obtained when only symmetric Doppler counts > 10 are selected (together with 3σ iterations). There are four such double pass determinations for HNL site 40 with a height of $1.57 \pm 5.52(\sigma) \pm 2.76(\sigma_m)$ m and six such double pass determinations for HNL site 41 with a height of $6.50 \pm 15.64(\sigma) \pm 6.39(\sigma_m)$ meters.

The fact that the height difference between satellite 65 and the remaining ones is larger in Suva (in 1971) than in Honolulu (in 1973/1974) may indicate that the height is either site- or epoch-dependent. Perhaps the accuracy of the orbital parameters has increased with time through better modelling of the earth's gravity field.

Problem sites

Problem sites are those where the fixes returned by the satellite navigator show a rather large scatter when the ship is in a fixed position, a sufficient number of satellite passes is available, and the initialized antenna height is sufficiently close to the true height. Callao (Peru) was recognized early, even from on board ship, as being such a site. Using the

double-pass method and 3σ or 2σ iterations on the data does not eliminate the large spread, and a problem site therefore can be considered more specifically as one where the σ of the double-pass observation is larger than on other sites, especially on the antenna heights for a sufficiently large data set. Table 1 and the corresponding computer plots (Appendix Group I) show that even after the tight 2σ iterations, the standard deviation of single double-pass height for Callao in 1972 and 1974 (as well as for Acapulco in 1972) gives rather large values or more than 40 meters. A similar large standard deviation is obtained for the double-pass longitude determinations (see computer plots, Appendix Group I, for sites 43, 44, and 45). The data in 1972 seem, however, of better quality (sites 16 and 17).

As Table 5 indicates, selection of double passes with a high number of symmetric Doppler counts (> 8) does not reduce the spread. The particularly bad data on site 44 (Callao B) might be due in part to the fact that a large grain elevator was quite close to the docking position of the Kana Keoki so the selection by symmetric Doppler counts was not run on the computer. Similarly the longitudes of the double-pass fixes for site 43 (15 observations remaining with > 8 symmetric counts and 3σ iterations) still show a large spread and a large 76-m standard deviation (see computer plots).

The writer was told by Hawaii Institute of Geophysics personnel that once the ship leaves port, the fixes obtained on route seem normal again.

The reasons for the larger spread of fixes in Callao are not known. Radio (or television) interference might cause problems, or atmospheric conditions might cause anomalously large changes in the tropospheric refractive index.

SEA LEVEL AND GEOIDAL HEIGHTS

As stated earlier, reasonably good results are obtained when the standard deviation (σ) of the antenna height or longitude of a single double-pass observation in a larger data set is 20 m or less after the 2σ iterations. The fixed position requirement is certainly fulfilled for the fixes obtained by the R. V. Kana Keoki when it is tied to a dock in a harbor and good results were also obtained in one case when the ship was anchored (see site 21, Punta Arenas, Table 2 and the corresponding computer plot Group I).

As for the Glomar Challenger, the position of the ship between two consecutive orbits of a double pass does not seem to vary enough to affect the antenna height results. In the case of DSDP site 410/410A, the longitudes of the SAT NAV output were corrected to the hydrophone beacon position (assuming $x = 0$, $y = 0$ is at the location of the drill). The ship's bow direction (from the gyro heading) was also taken into account. These corrections were applied to double passes of satellite No. 12. The antenna height found for the five double passes of satellite 12 (retained after the 2σ iterations of the computer) was 74.13 m ($\sigma = 5.48$) as compared to 74.89 m ($\sigma = 5.21$) when position corrections were applied and 75.79 m ($\sigma = 7.30$) from all 15 double passes retained, but uncorrected.

A better (satellite-determined) beacon position is obtained for longitude and latitude. The $\sigma = 25.8$ m for the uncorrected longitude values of the five double passes retained of satellite 12 reduces to 18.4 m after corrections and compares to 27.1 m for all 15 uncorrected double passes. Similarly applying corrections to the latitude data (satellite 12, five double passes) reduces the σ by 10%. It would appear therefore that first

reducing the SAT NAV fixes to the beacon position would improve the overall accuracy of the site coordinates. The *Glomar Challenger* double pass fixes at drill site location seem at least as accurate as, if not better than, the harbor data on board the *Kana Keoki*. This might be due to the difference in epoch, to the DSDP data being more recent, to the incidentally better elevation angle distribution resulting in a higher number of symmetric Doppler counts and to more stable tropospheric conditions. In retrospect it also appears that the very slow speeds involved in moving the *Glomar Challenger* around the beacon position (of the order of a few 0.001 knots), do not influence the fix results. This conclusion seems reasonable when one compares the fix errors resulting from speed errors in northerly or easterly direction (Stansell, 1976, his figures p. 490 and 491) over most of the satellite maximum elevation angle range used for the double pass determinations.

Finally in Table 6 and Figure 10, sea level height with respect to the Navy navigation satellite reference ellipsoid are compared to two different geoid models. The sea level heights are those determined from double passes during the present investigation by subtracting the antenna's height above the ship's waterline from the antenna height determined from the double passes. Details of antenna height have been supplied by Ted Gustafson (Scripps Institution of Oceanography) to the nearest inch for DSDP sites 407, 410, and 412. For other DSDP sites this height was assumed to be 21.9 m (last column in Table 6). The height for the *Kana Keoki* antenna was taken from the ship's plans and a waterline when the ship was in Honolulu and is close to 18 meters. Geoidal heights were read off two different maps. The one used under "SAT NAV MANUAL" is identical to the one published by Stansell (1976, his figure p. 488) with 10-m contour intervals (missing in some parts

of the map). The map used under GEM 6 was a model prepared and published by the Defense Mapping Agency Topographic Center, Washington, D. C., June 1974. Figure 11 shows the Kana Keoki sites and DSDP site together with GEM 6 geoidal heights. Since both maps were rather small, geoidal heights in Table 6 are probably no better than 1 to 2 meters near smooth topography and errors are possibly larger at locations with steep gradients. The standard deviation (σ) and the deviation of the mean (σ_m) in Table 6 are those of the data remaining after the (usually 2σ) iterations on height, followed by iterations on longitude of the remaining data. σ and σ_m are therefore too small. As a consequence the 95% confidence interval of the mean based on σ_m and the number of remaining observations is also somewhat too small (Table 6, Fig. 10).

As Table 6 and Figure 10 show, despite the underestimate of the 95% confidence intervals, the sea level heights determined at all the DSDP sites in the open ocean are within the 95% confidence interval when compared to the GEM 6 geoidal height model and when compared to the geoidal height map of the SAT NAV manual, except for site 354 where a rather large difference exists between the SAT NAV manual and GEM 6 model. This site is located north of the north coast of Brazil in the geoidal valley leading to the minimum near 60^{o}W longitude and 20^{o}N latitude on the GEM 6 map.

Sea level heights determined in harbors onboard the Kana Keoki in some locations seem to differ from the GEM 6 geoidal height model. Among those locations are (see Table 6, Fig. 10): Suva (data taken 1971, 1972), Wellington (1971), Quayaquil (1972) and Panama (1974), all located in areas of relatively steep geoidal height gradients.

The largest deviations from the GEM 6 model at Panama and Quayaquil are near 20 meters. As Marsh et al. (1976) have shown, differences of more

than 20 m exist between the GEM 6 and SAO SE III models and also between the Sky Lab altimeter data from a continuous revolution on January 31, 1974 and the GEM 6 model.

The GEM 8 model map published by King-Hele (1976) is too small and the print too weak to allow determination of the heights of a number of sites; however, most of the sea levels given here seem to agree better with GEM 8 than GEM 6, where a reasonable check was possible.

CONCLUSIONS

The double pass method allows three-dimensional fixes from the Navy navigation satellite system for a fixed antenna position; only latitude, longitude, satellite elevation angle, geometry of the passes, and the satellite identification are needed from the satellite navigator printout. Sea level or geoidal heights therefore are obtained from shipboard fixes in harbors and from the Glomar Challenger when it is in a fixed position over an acoustic transponder in the open sea.

The accuracy, measured by the standard deviation (σ) of a double pass, is 20 m or better in height and longitude after "erratic" or "bad" data have been eliminated that are outside a specified limit, for this investigation usually 2σ in height, followed by elimination of data outside 2σ in longitude, for sufficiently large data sets.

The small and slow motions of the Glomar Challenger over the transponder do not seem to affect significantly the height determinations, whereas correcting longitude and latitudes to the transponder coordinates seems to diminish the standard deviation of these observations.

Sea level determinations at eight DSDP open ocean sites and nine Kana Keoki harbor sites (Table 6 and Fig. 10) are within about 20 m of the model GEM 6 geoidal heights. Most of the observed heights seem to be closer to those of the GEM 8 model; however, the smallness and weak print of the published (King-Hele, 1976) map did not allow a tabulation. The standard deviations of the mean height for a four-day observation period are less than 4 m, reaching as low as 1.9 meters. This limit can be reduced further by obtaining Doppler fixes only from satellites in a double pass configuration.

Most important perhaps is the fact that open-ocean sea level is determined by an independent method, and when compared to the Sky Lab altimetry data, is not affected by uncertainties in a single orbit position determination but rather represents an average over many passes of several satellites.

Incidentally better positions for the Glomar Challenger ((x,y) = (0.0) beacon position) are obtained when beacon position corrections are applied to the satellite navigator positions. Using satellite 12 (30120) for site 410, a reduction of σ from 25 to 18 m in longitude and about 10% in latitude was found. It appears therefore that after application of the reductions, the open-sea fixes are of the same quality as those of the Kana Keoki in a fixed harbor location, indicating that the (x,y) = (0.0) position error (σ_m) after four days of satellite navigation fixes should be no more than 10 m in longitude and in latitude.

ACKNOWLEDGMENTS

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Special recognition is due to Duncan M. Chesley, who developed the computer programs and plotting routines used for presentation of the results.

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TABLES

*** RAW DATA ***

TABLE 1 A

1972 KK HNL HT: +23 M # 25

NO.	DAY	HR	MIN	SAT	ELV	LATITUDE	LONGITUDE	ITER	DOP.	CT.	
1	306	23	24	54	53	21 18.822N	157 52.014W	2	20	0	S-W
2	307	1	46	63	46	21 18.777N	157 52.020W	2	22	2	N-E
3	307	3	28	67	18	21 18.792N	157 52.023W	2	17	7	N-E
4	307	5	8	67	31	21 18.798N	157 52.033W	2	26	14	N-W
5	307	5	44	64	8	21 18.759N	157 51.937W	3	6	1	N-E
6	307	7	26	64	80	21 18.802N	157 51.906W	5	32	1	N-W
7	307	9	18	64	7	21 18.955N	157 51.970W	4	0	0	N-W
8	307	11	48	65	77	21 18.851N	157 52.349W	5	24	1	S-W
9	307	13	36	65	7	21 18.715N	157 52.117W	2	0	0	S-W
10	307	14	54	63	39	21 18.849N	157 52.014W	2	34	16	S-W
11	307	18	52	42	38	21 18.819N	157 52.033W	2	28	11	S-E
12	307	20	38	64	17	21 18.801N	157 52.022W	2	17	6	S-W
13	307	22	34	54	44	21 18.813N	157 52.023W	2	30	15	S-E
14	308	0	22	54	18	21 18.844N	157 52.040W	2	21	5	S-W
15	308	0	58	63	16	21 18.779N	157 51.956W	2	12	0	N-E
16	308	1	24	65	9	21 18.806N	157 52.036W	2	11	1	N-W
17	308	2	44	63	46	21 18.782N	157 52.020W	2	31	15	N-W
18	308	8	30	42	26	21 18.847N	157 51.844W	4	12	1	N-W
19	308	10	20	54	34	21 18.796N	157 52.009W	2	31	2	N-E
20	308	11	0	65	34	21 18.827N	157 52.012W	2	28	14	S-E
21	308	12	6	54	26	21 18.774N	157 52.025W	2	25	3	N-W
22	308	12	46	65	21	21 18.845N	157 52.031W	2	25	12	S-W
23	308	14	6	63	74	21 18.807N	157 52.044W	2	30	1	S-E
24	308	15	54	63	9	21 18.805N	157 52.051W	3	12	5	S-W
25	308	18	4	64	17	21 18.817N	157 51.994W	2	20	2	S-E
26	308	19	46	42	66	21 18.838N	157 51.615W	2	32	10	S-W
27	308	21	44	54	15	21 18.827N	157 52.018W	2	19	5	S-E
28	308	22	48	65	30	21 18.809N	157 52.005W	2	30	5	N-E
29	308	23	28	54	52	21 18.821N	157 52.023W	2	34	16	S-W
30	309	0	36	65	28	21 18.795N	157 52.033W	2	28	14	N-W
31	309	1	56	63	54	21 18.799N	157 52.012W	2	21	1	N-E
32	309	3	42	63	10	21 18.778N	157 52.055W	4	15	7	N-W
33	309	5	48	42	7	21 18.606N	157 51.881W	3	6	2	N-E
34	309	7	30	42	68	21 18.793N	157 51.908W	2	31	0	N-W
35	309	9	22	42	7	21 19.118N	157 51.904W	4	0	0	N-W
36	309	9	36	54	11	21 18.842N	157 52.036W	3	9	1	N-E
37	309	10	14	65	11	21 18.813N	157 52.022W	4	15	7	S-E
38	309	11	14	54	71	21 18.780N	157 52.025W	3	36	17	N-W
39	309	11	56	65	59	21 18.825N	157 52.027W	2	32	15	S-W
40	309	13	6	54	7	21 18.920N	157 52.131W	9	0	0	N-W
41	309	13	20	63	32	21 18.830N	157 52.020W	2	24	0	S-E
42	309	15	4	63	28	21 18.839N	157 52.012W	2	27	0	S-W
43	312	3	2	63	22	21 18.776N	157 52.033W	2	26	12	N-W
44	312	6	34	42	35	21 18.796N	157 52.001W	2	27	12	N-E
45	312	6	56	64	77	21 18.803N	157 52.064W	3	34	1	N-E
46	312	8	18	42	23	21 18.778N	157 52.022W	2	28	13	N-W
47	312	8	46	64	9	21 18.887N	157 52.029W	3	12	5	N-W
48	312	10	26	54	57	21 18.794N	157 52.029W	2	35	17	N-E
49	312	11	18	65	76	21 18.815N	157 51.996W	2	34	16	S-E
50	312	12	14	54	15	21 18.776N	157 52.036W	2	23	11	N-W
51	312	12	38	63	17	21 18.822N	157 52.016W	2	24	3	S-E
52	312	13	6	65	8	21 18.705N	157 52.071W	2	6	2	S-W
53	312	14	22	63	51	21 18.823N	157 52.018W	2	36	17	S-W
54	312	17	54	42	14	21 18.801N	157 51.998W	2	19	5	S-E
55	312	18	24	64	38	21 18.825N	157 52.022W	2	24	7	S-E
56	312	19	40	42	55	21 18.835N	157 52.025W	2	30	14	S-W
57	312	20	8	64	22	21 18.836N	157 52.018W	2	23	6	S-W
58	312	21	50	54	26	21 18.818N	157 52.027W	2	26	3	S-E
59	312	23	6	65	58	21 18.803N	157 52.018W	2	26	1	N-E
60	312	23	36	54	30	21 18.827N	157 52.025W	2	29	4	S-W
61	313	0	30	63	12	21 18.799N	157 51.996W	4	11	4	N-E
62	313	0	56	65	11	21 18.858N	157 52.023W	2	13	0	N-W
63	313	2	12	63	57	21 18.772N	157 52.020W	2	26	0	N-W

SELECTION CRITERIA: PASSES WITH THE FOLLOWING TRAITS HAVE BEEN RETAINED.

ELEVATION ANGLE: 5 TO 75 DEGREES
ITERATIONS: FEWER THAN 6
SECOND SIDE DOPPLER COUNT: MORE THAN -1

TABLE 1 B

INDEX	SAT	PAIRS		DAY
1	67	3	4	307
2	54	13	14	307
3	63	15	17	308
4	54	19	21	308
5	65	20	22	308
6	63	23	24	308
7	54	27	29	308
8	65	28	30	308
9	63	31	32	309
10	42	33	34	309
11	54	36	38	309
12	65	37	39	309
13	63	41	42	309
14	42	44	46	312
15	54	48	50	312
16	63	51	53	312
17	42	54	56	312
18	64	55	57	312
19	54	58	60	312
20	65	59	62	312
21	63	61	63	313

1972 KK HNL HT: +23 M # 25

DATA BELOW ARE FOR DAYS 306- 313

PAIR	ANT. HT.	LONGITUDE DEG.	LONGITUDE MINUTES
1	33.43	157.	52.0272
2	37.34	157.	52.0341
3	76.04	157.	51.9765
4	37.78	157.	52.0177
5	41.36	157.	52.0229
6	25.61	157.	52.0501
7	26.71	157.	52.0194
8	49.70	157.	52.0193
9	54.54	157.	52.0446
10	36.15	157.	51.8853
11	18.29	157.	52.0344
12	26.23	157.	52.0231
13	15.57	157.	52.0158
14	42.62	157.	52.0129
15	27.63	157.	52.0342
16	24.49	157.	52.0166
17	41.86	157.	52.0048
18	19.40	157.	52.0196
19	21.05	157.	52.0260
20	26.31	157.	52.0219
21	39.20	157.	52.0016

1972 KK HNL HT: +23 M # 25

TABLE 1 C

DATA BELOW ARE FOR DAYS 306- 313

```
MEAN LONGITUDE:                 157.      52.0146 MINUTES

                         STD. DEV.:       0.0334 MINUTES (    57.70 METERS)
                      DEV. OF MEAN:       0.0073 MINUTES (    12.59 METERS)

MEAN LATITUDE:                   21.      18.8042 MINUTES

                         STD. DEV.:       0.0386 MINUTES (    71.46 METERS)
                      DEV. OF MEAN:       0.0060 MINUTES (    11.03 METERS)

MEAN ANTENNA HEIGHT:    34.35 METERS
STD. DEV.:              14.18 METERS
DEV. OF MEAN:            3.09 METERS

   ***  LATITUDE CORRECTION APPLIED  ***

 . . . . . . . . . . . CORRECTING HEIGHTS . . . . . . . .

   THROUT: THE FOLLOWING ELEMENTS HAVE BEEN REMOVED:

     ELEMENT    3 WAS    2.94 SIGMA FROM THE MEAN

MEAN LONGITUDE:                 157.      52.0166 MINUTES

                         STD. DEV.:       0.0331 MINUTES (    57.13 METERS)
                      DEV. OF MEAN:       0.0074 MINUTES (    12.78 METERS)

MEAN LATITUDE:                   21.      18.8054 MINUTES

                         STD. DEV.:       0.0391 MINUTES (    72.55 METERS)
                      DEV. OF MEAN:       0.0062 MINUTES (    11.47 METERS)

MEAN ANTENNA HEIGHT:    32.26 METERS
STD. DEV.:              10.75 METERS
DEV. OF MEAN:            2.40 METERS

   THROUT: THE FOLLOWING ELEMENTS HAVE BEEN REMOVED:

     ELEMENT    9 WAS    2.07 SIGMA FROM THE MEAN

MEAN LONGITUDE:                 157.      52.0151 MINUTES

                         STD. DEV.:       0.0333 MINUTES (    57.52 METERS)
                      DEV. OF MEAN:       0.0076 MINUTES (    13.20 METERS)

MEAN LATITUDE:                   21.      18.8062 MINUTES

                         STD. DEV.:       0.0399 MINUTES (    73.96 METERS)
                      DEV. OF MEAN:       0.0065 MINUTES (    12.00 METERS)

MEAN ANTENNA HEIGHT:    31.09 METERS
STD. DEV.:               9.65 METERS
DEV. OF MEAN:            2.21 METERS

   THROUT: NO VALUES OUTSIDE YOUR 2.00  SIGMA LIMIT

 . . . . . . . . . . . . . . . . . . . . . . . . .

   HEIGHTS COMPLETED     2 DROPPED FROM ORIGINAL  21
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. . . .

. . . . . CORRECTING LONGITUDES . . .

TABLE 1 D

```
THROUT: THE FOLLOWING ELEMENTS HAVE BEEN REMOVED:
  ELEMENT  10 WAS   3.90 SIGMA FROM THE MEAN

MEAN LONGITUDE:             157.     52.0223 MINUTES

                       STD. DEV.:     0.0113 MINUTES (   19.57 METERS)
                    DEV. OF MEAN:     0.0027 MINUTES (    4.61 METERS)

 MEAN LATITUDE:              21.     18.8123 MINUTES

                       STD. DEV.:     0.0223 MINUTES (   41.25 METERS)
                    DEV. OF MEAN:     0.0037 MINUTES (    6.88 METERS)

MEAN ANTENNA HEIGHT:   30.81 METERS
STD. DEV.:              9.85 METERS
DEV. OF MEAN:           2.32 METERS


THROUT: THE FOLLOWING ELEMENTS HAVE BEEN REMOVED:
  ELEMENT   6 WAS   2.45 SIGMA FROM THE MEAN

MEAN LONGITUDE:             157.     52.0207 MINUTES

                       STD. DEV.:     0.0092 MINUTES (   15.95 METERS)
                    DEV. OF MEAN:     0.0022 MINUTES (    3.87 METERS)

 MEAN LATITUDE:              21.     18.8125 MINUTES

                       STD. DEV.:     0.0229 MINUTES (   42.38 METERS)
                    DEV. OF MEAN:     0.0039 MINUTES (    7.27 METERS)

MEAN ANTENNA HEIGHT:   31.12 METERS
STD. DEV.:             10.06 METERS
DEV. OF MEAN:           2.44 METERS


THROUT: THE FOLLOWING ELEMENTS HAVE BEEN REMOVED:
  ELEMENT  21 WAS   2.07 SIGMA FROM THE MEAN

MEAN LONGITUDE:             157.     52.0219 MINUTES

                       STD. DEV.:     0.0081 MINUTES (   13.95 METERS)
                    DEV. OF MEAN:     0.0020 MINUTES (    3.49 METERS)

 MEAN LATITUDE:              21.     18.8142 MINUTES

                       STD. DEV.:     0.0222 MINUTES (   41.19 METERS)
                    DEV. OF MEAN:     0.0039 MINUTES (    7.28 METERS)

MEAN ANTENNA HEIGHT:   30.61 METERS
STD. DEV.:             10.16 METERS
DEV. OF MEAN:           2.54 METERS


THROUT: THE FOLLOWING ELEMENTS HAVE BEEN REMOVED:
  ELEMENT  17 WAS   2.11 SIGMA FROM THE MEAN

MEAN LONGITUDE:             157.     52.0230 MINUTES

                       STD. DEV.:     0.0069 MINUTES (   11.94 METERS)
                    DEV. OF MEAN:     0.0018 MINUTES (    3.08 METERS)

 MEAN LATITUDE:              21.     18.8140 MINUTES

                       STD. DEV.:     0.0225 MINUTES (   41.73 METERS)
                    DEV. OF MEAN:     0.0041 MINUTES (    7.62 METERS)

MEAN ANTENNA HEIGHT:   29.86 METERS
STD. DEV.:             10.05 METERS
DEV. OF MEAN:           2.60 METERS


THROUT: NO VALUES OUTSIDE YOUR 2.00  SIGMA LIMIT

. . . . . . . . . . . . . . . . . . . . . . . . . .

LONGITUDES COMPLETED.    4 MORE PAIRS DROPPED

. . . . . . . . . . . . . . . . . . . . . . . . . .
```

FINAL RESULTS

TABLE 2. KANA KEOKI ANTENNA HEIGHTS (in meters) [Subtract 17 m for GEOID].

SITE	DATE	LOCATION	INITIALIZED HT-	NO. OF DOUBLE PASSES	3σ ITERATIONS NO. REJECTED	3σ ITERATIONS HT	3σ ITERATIONS σ	3σ ITERATIONS σ_m	2σ ITERATIONS NO. REJECTED	2σ ITERATIONS HT	2σ ITERATIONS σ	2σ ITERATIONS σ_m
10	1971 146-149	Ponape	50	10	--	38.1	38.9	12.3	1	46.0	31.7	10.6
11	167-171	Palau	78	17	--	60.7	30.1	7.3	3	69.0	20.4	5.4
12	201-202	Suva	75	4	--		same		-	46.8	18.6	8.3
13	202-207	Suva	75	28	--	59.6	16.5	3.1	4	55.7	14.1	2.9
14	207-214	Suva	54	39	1	52.0	17.7	2.9	19	48.9	7.3	1.6
15	241-244	Wellington	35	21	3	45.3	9.5	2.3	9	41.7	8.7	2.5
16	1972 15-22	Callao 9-D	33	37	2	29.4	38.7	6.5	18	25.2	26.4	6.1
17	54-58	Callao 4-A	28	31	3	30.6	35.2	6.7	7	28.0	34.4	7.0
19	* 74-75	Talara	28	7	--		same		-	-10.5	53.4	20.2
20	104-111	Quayaquil	30	44	2	6.1	22.4	3.5	11	6.1	19.2	3.3
21	*122-123	Punta Arenas	15	6	--		same		-	15.0	18.1	7.4
22	132-133	Acapulco I	0	7	--		same		-	-122.8	130.7	49.4
23A	133-134	Acapulco II	0	5	--		same		-	-94.4	91.5	40.9
23B	136-138	Acapulco II	14	5	--		same		-	-37.4	110.5	49.4
24	203	Midway	5	5	--		same		-	18.8	14.3	6.4
25	306-313	HNL	23	21	1	34.3	14.5	3.3	6	29.9	10.1	2.6
26	309-311	HNL	23	15	1	25.6	13.9	3.7	2	23.9	12.8	3.6
28	359-360	Suva	59	8	--	58.2	20.1	7.1	1	52.3	12.1	4.6
29	360-362	Suva	59	13	--		same		-	50.3	16.4	4.5
30	1973 21-21	Papeete	28	2	--		same		-	16.3	26.0	18.4
32	50-51	Quayaquil	28	6	--		same		-	38.1	49.4	20.2
34	91-93	Antofagasto	34	18	--	65.9	34.2	8.1	3	57.1	25.2	6.5
37	151-152	Papeete	28	5	--		same		-	14.2	15.2	6.8
38	204-207	HNL	24	10	--	33.2	25.1	8.0	2	22.7	10.8	3.8
39A	251-252	HNL	19	10	--	23.0	26.7	8.4	2	12.3	12.0	4.2
39B	252-253	HNL	24	7	--		same		-	35.1	27.9	10.6
40	290-297	HNL	24	51	6	19.0	34.3	5.1	18	19.7	18.4	3.2
41	1973/74 353-7	HNL	19	130	13	21.8	16.8	1.6	65	21.0	8.9	1.1
42	1974 9	HNL	19	4	--		same		-	11.6	49.1	24.6
43	72-90	Callao A	38	70	8	116.7	51.0	6.5	20	90.1	40.3	5.7
44	90-99	Callao B		16					4	271.9	508.8	146.9
45	99-101	Callao D	38	14			same		-	45.1	47.2	12.6
46	142-146	Valparaiso	39	11	--	77.7	138.5	41.8	2	54.8	25.6	8.5
47	168-172	Panama	19	22	2	- 1.1	15.6	3.5	6	+ 1.9	14.4	3.6

Table 3

SUVA ANTENNA HEIGHTS

A

SITE #		DATE	3σ ITERATIONS HT	σ	σ_m	NO. OBSERV.	2σ ITERATIONS HT	σ	σ_m	NO. OBSERV.
12	1971	201-202	46.82	18.58	8.31	4	46.82	18.58	8.31	4
13		202-207	59.59	16.50	3.12	28	55.66	14.11	2.88	24
14		207-214	52.01	17.74	2.88	38	48.87	7.34	1.64	20
28	1972	359-360	58.23	20.13	7.12	8	52.32	12.11	4.58	7
29		360-362	50.29	16.38	4.54	13	50.29	16.38	4.54	13
All Height from above:			54.33	17.55	1.83	92	52.10	15.17	1.63	87

B

3σ ITERATION on

	> 5 symmetric Doppler cts.				> 8 symmetric Doppler cts.			
12	45.80			1	none			
13	59.88	15.88	3.46	21	57.04	14.99	3.53	18
14	50.80	17.38	3.41	26	51.06	20.54	4.96	17
28	49.77	14.24	7.12	4	46.69	15.73	9.08	3
29	54.59	13.86	4.62	9	52.16	12.60	4.46	8
All 5 summed:	54.34			61	53.31			46

C

3σ iterations by Satellite

SAT #	Site #13				Site #14			
42	52.78	18.25	7.45	6	*55.64	13.27	5.02	7
54	72.54	19.59	8.76	5	63.84	20.43	8.34	6
63	66.44	9.80	3.70	7	58.51	18.21	6.07	9
64	56.75	13.70	5.18	7	53.41	9.26	3.50	7
65	42.27	4.94	2.85	3	33.70	11.06	3.70	9

*one value dropped

TABLE 4A. Comparison Honolulu Antenna Heights (in meters)

SITE	DATE		3σ ITERATIONS HT	σ	σ_m	NO. OF OBSERV.	2σ ITERATIONS HT	σ	σ_m	NO. OF OBSERV.
25	1972	306-313	34.26	14.54	3.25	20	29.86	10.05	2.60	15
26		309-311	25.62	13.88	3.71	14	23.91	12.83	3.56	13
38	1973	204-207	33.16	25.14	7.95	10	22.66	10.78	3.81	8
39A		251-252	23.04	26.67	8.44	10	12.27	11.97	4.23	8
39B		252-253	35.08	27.92	10.55	7	35.08	27.92	10.55	7
40		290-297	18.96	34.31	5.11	45	19.65	18.39	3.20	33
41	1973/74	353-007	21.76	16.81	1.55	117	20.96	8.94	1.11	65
42	1974	9-9	11.56	49.11	24.55	4	11.56	49.11	24.55	4

All heights from above data together: Iterations on height only (on HP45) total double pass 248.

			HT	σ	σ_m	NO. OF OBSERV.	HT	σ	σ_m	NO. OF OBSERV.
			24.44	18.66	1.23	229	22.58	13.57	0.96	198

TABLE 4B. Honolulu Antenna Heights (in meters)

Different selection criteria

For all satellites: elevation angle 5 to 75° and fewer than 6 iterations in computing a single pass fix

SELECTION ST. DEV	SYM. CTS.	SITE 40 HT	σ	σ_m	NO. OF OBSERV.	SITE 41 HT	σ	σ_m	NO. OF OBSERV.
3σ	all	18.96	34.31	5.11	45	21.76	16.81	1.55	117
2σ	all	19.65	18.39	3.20	33	20.96	8.94	1.11	65
3σ	> 4	14.31	17.71	4.43	16	19.94	15.51	1.89	67
3σ	> 5	15.49	17.66	4.56	15	--	--	--	--
3σ	> 6	14.31	17.75	4.75	14	20.49	16.02	2.16	55
3σ	> 8	26.16	33.51	9.67	12	17.28	14.42	2.31	39
		*(17.82)	(17.78)	(5.36)	(11)				
3σ	>10	25.87	40.27	14.24	8	13.75	12.25	2.89	18
		*(12.71)	(16.64)	(6.29)	(7)	*(15.82)	(8.79)	(2.13)	(17)

*One extreme value on height dropped from line above.

TABLE 4C. Antenna Heights, HNL Site 41 by Individual Satellites

SAT. NO.	3 ITERATIONS HT	σ	σ_m	NO. OF OBSERV.	2 ITERATIONS HT	σ	σ_m	NO. OF OBSERV.
42	23.04	12.99	2.71	23	21.57	10.09	2.45	17
54	23.93	14.75	3.08	23	19.62	6.81	1.60	18
63	-36.11*	132.55	50.1	7	*same			
64	29.94	10.92	2.33	22	25.90	7.89	1.91	17
65	13.60	23.46	4.6	26	10.47	22.80	5.53	17
99	17.63	10.76	2.35	21	13.70	9.72	2.51	15
FOR COMPARISON:								
All	21.76	16.81	1.55	117	20.96	8.94	1.11	65

*Two bad values retained, dropping the two:	39.36	21.51	9.62	5

TABLE 5. Antenna Heights, Selection by Doppler Counts and 3σ Iterations

SITE	DATE		> 5 Symmetric Doppler Cts. HT	σ	σ_m	NO. OF OBSERV.	> 8 Symmetric Doppler Cts. HT	σ	σ_m	NO. OF OBSERV.
CALLAO										
16	1972	15-22	44.6	33.7	8.7	15	47.4	37.9	12.0	10
17	1972	54-58	33.2	31.0	7.5	17	34.1	25.1	7.5	12
43	1974	72-90	108.7	53.8	8.11	44	121.1	75.4	19.5	15
45	1974	99-101	42.6	54.3	31.3	3	23.3	--	--	1
PALAU										
11	1971	167-171	65.2	23.0	6.9	11	64.3	15.0	6.1	6
WELLINGTON										
15	1971	241-244	44.6	8.7	2.4	13	44.6	8.7	2.4	13
QUAYAQUIL										
20	1972	104-111	11.1	20.7	4.8	19	12.0	23.9	8.5	8
32	1973	50-51	39.2	55.1	24.7	5	135.9	--	--	1
			*(15.0)	(12.4)	(6.2)	(4)				
PANAMA										
47	1974	168-172	1.3	28.3	7.6	14	- 1.4	31.2	9.4	11
			*(-4.9)	(16.6)	(4.6)	(13)				

*One "bad" double pass removed from line above.

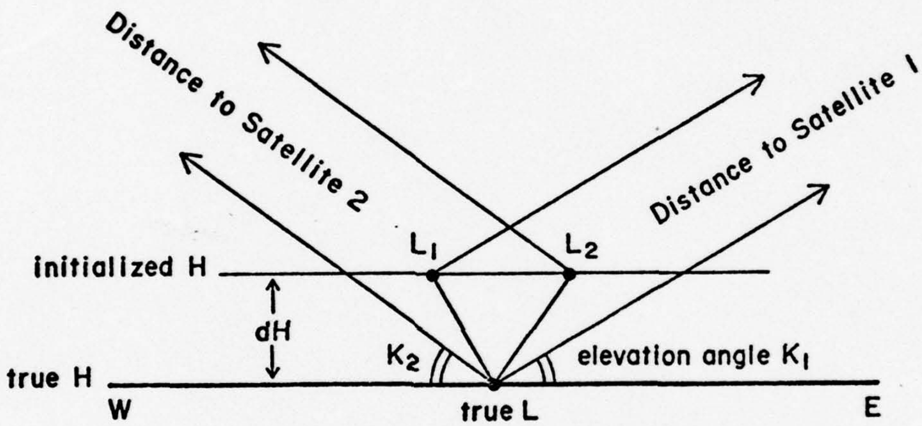
TABLE 6

SEA LEVEL--GEOID HEIGHT COMPARISON
(in meters)

SITE	GEOID HEIGHT		SEA LEVEL W. RESP. TO SATELLITE REF.					
	SAT NAV MANUAL	GEM 6	SEA LEVEL	95% CONFIDENCE	σ	σ_M	No. of OBSERV.	ANT HT above Sea Level
GLOMAR CHALLENGER								
354 DSDP	-12 to -15	-35	- 42.6	12.0	17.9	5.4	11	21.9
355	0 to - 5	-10	- 27.4	30.5	36.6	12.9	8	21.9
356	0	- 5	- 4.2	16.6	18.1	6.8	7	21.9
357	- 2 to - 5	-5 to -6	- 7.7	16.4	13.9	5.9	5	21.9
358	- 9 to -10	-5 to -6	- 10.7	5.0	5.9	2.1	8	21.9
407	+55	+55	50.7	7.8	9.4	3.3	8	21.7
410	+51	55 to 60	53.9	4.0	7.3	1.9	15	21.9
412(A*)	42 ± 2	40 ± 2	39.80	16.5	17.85	6.75	7	22.0
KANA KEOKI								
all Honolulu	+ 4 to +5	0 to +1	+ 4.6	1.9	13.6	1.0	198	18
all Suva	45 ± 3	52 ± 2	34.1	3.2	15.2	1.6	87	18
10 Ponape	50	42	28.0	24.3	31.7	10.6	9	18
11 Palau	68 to 69	65 to 66	51.0	11.8	20.4	5.4	14	18
15 Wellington	15 ± 2	12 to 13	23.7	5.5	8.7	2.5	12	18
20 Quayaquil	--	+10	- 11.9	6.8	19.2	3.3	33	18
34 Antofagasta	19 to 20	+30	39.1	14.0	25.2	6.5	15	18
46 Valparaiso	20	19	36.8	19.7	25.6	8.5	9	18
47 Panama	0 to -2	+5 to +6	- 16.1	7.7	14.4	3.6	16	18

*Only first part of data used with initialized antenna height of 52 meters.

FIGURES



Distance to Satellite 2
Distance to Satellite 1
L1
L2
initialized H
dH
K2
elevation angle K1
true H
W
true L
E

FIG. 1

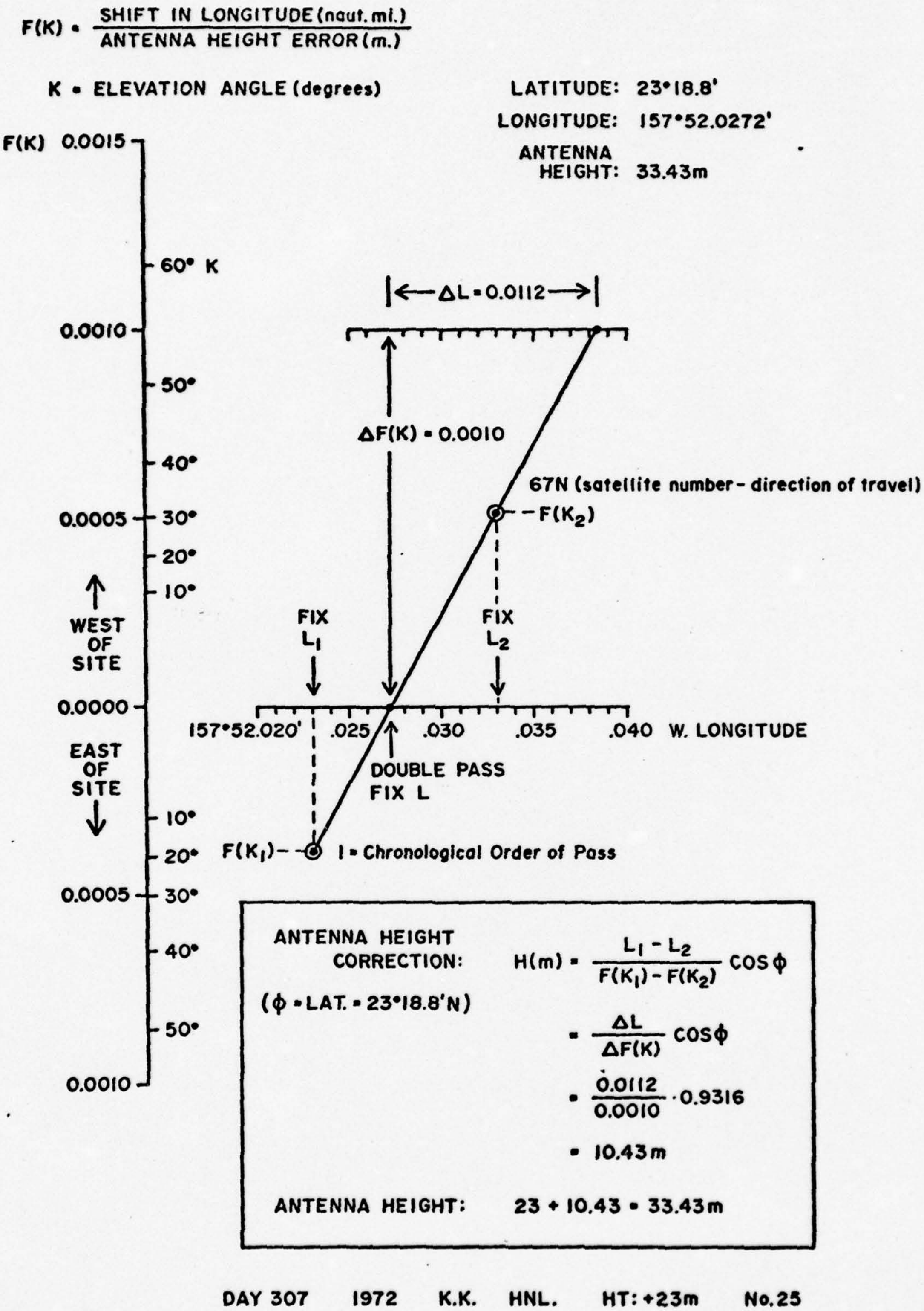
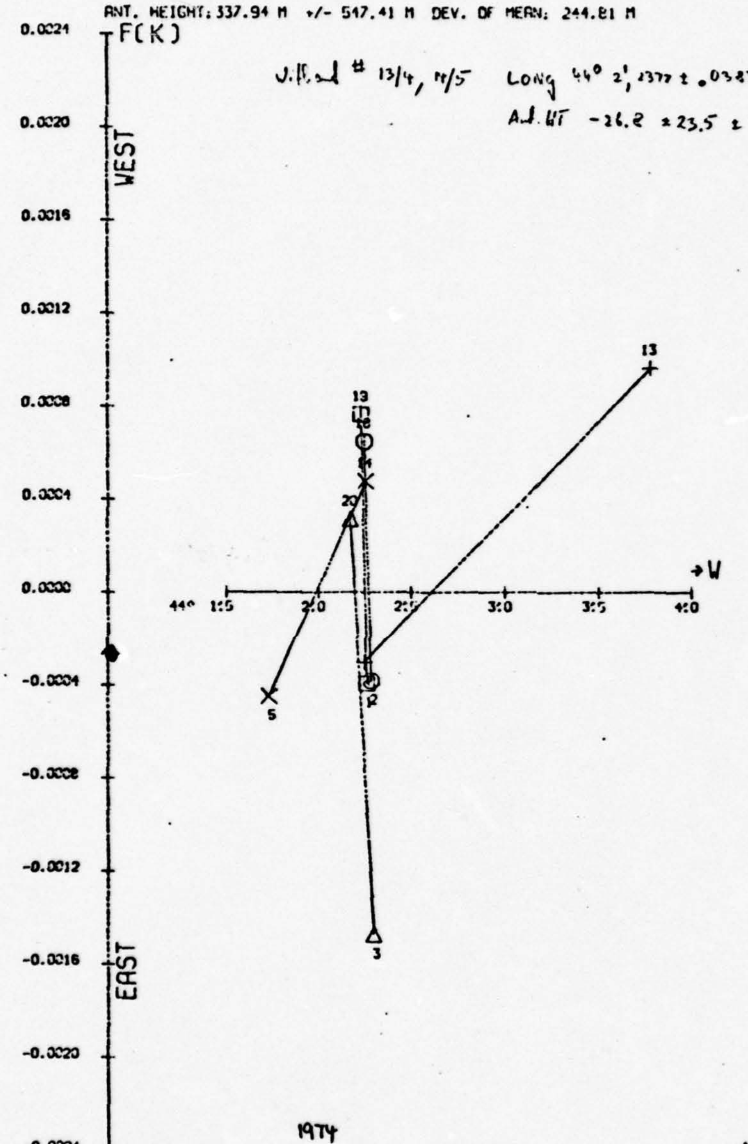

F(K) = SHIFT IN LONGITUDE (naut. mi.) / ANTENNA HEIGHT ERROR (m.)
K = ELEVATION ANGLE (degrees)
LATITUDE: 23°18.8'
LONGITUDE: 157°52.0272'
ANTENNA HEIGHT: 33.43m
F(K) 0.0015
60° K
0.0010
50°
40°
0.0005
30°
20°
10°
WEST OF SITE
0.0000
EAST OF SITE
10°
20°
0.0005
30°
40°
50°
0.0010
ΔL = 0.0112
ΔF(K) = 0.0010
67N (satellite number - direction of travel)
F(K2)
FIX L1
FIX L2
157°52.020'
.025
.030
.035
.040
W. LONGITUDE
DOUBLE PASS FIX L
F(K1)
1 = Chronological Order of Pass
ANTENNA HEIGHT CORRECTION:
(φ = LAT. = 23°18.8'N)
H(m) = (L1 - L2) / (F(K1) - F(K2)) COS φ
= ΔL / ΔF(K) COS φ
= 0.0112 / 0.0010 · 0.9316
= 10.43m
ANTENNA HEIGHT: 23 + 10.43 = 33.43m
DAY 307 1972 K.K. HNL. HT: +23m No. 25

FIG. 2

239

LAT.. 10° 54:9880 +/- 0:2336 (432.82 M) DEV. OF MERN: 0:0733 (135.87 M)
LONG. 44° 2:2621 +/- 0:2254 (410.17 M) 0:1008 (183.43 M)
ANT. HEIGHT: 337.94 M +/- 547.41 M DEV. OF MERN: 244.81 M



Long 44° 2!,1377 ± .0387 ± .0223
Ant. HT -26.2 ± 23.5 ± 13.6

1974
DAY 295-296 DSDP SITE 353 HT: +15 M (20)

FIG. 3

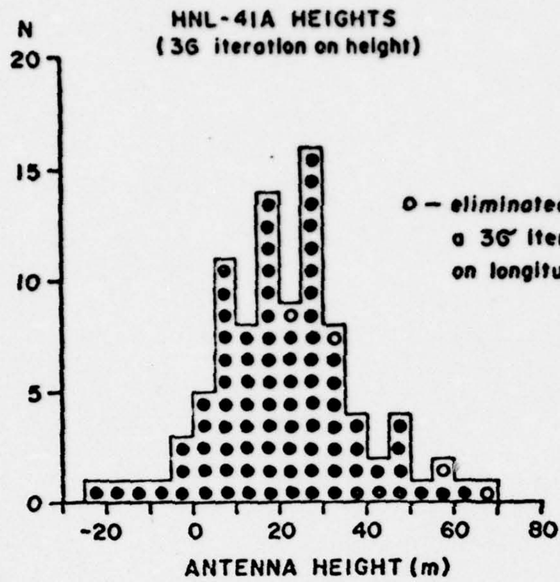

HNL-41A HEIGHTS
(3G iteration on height)
N
20
15
10
5
0
o — eliminated by
a 3G iteration
on longitude
-20
0
20
40
60
80
ANTENNA HEIGHT (m)

FIG. 4

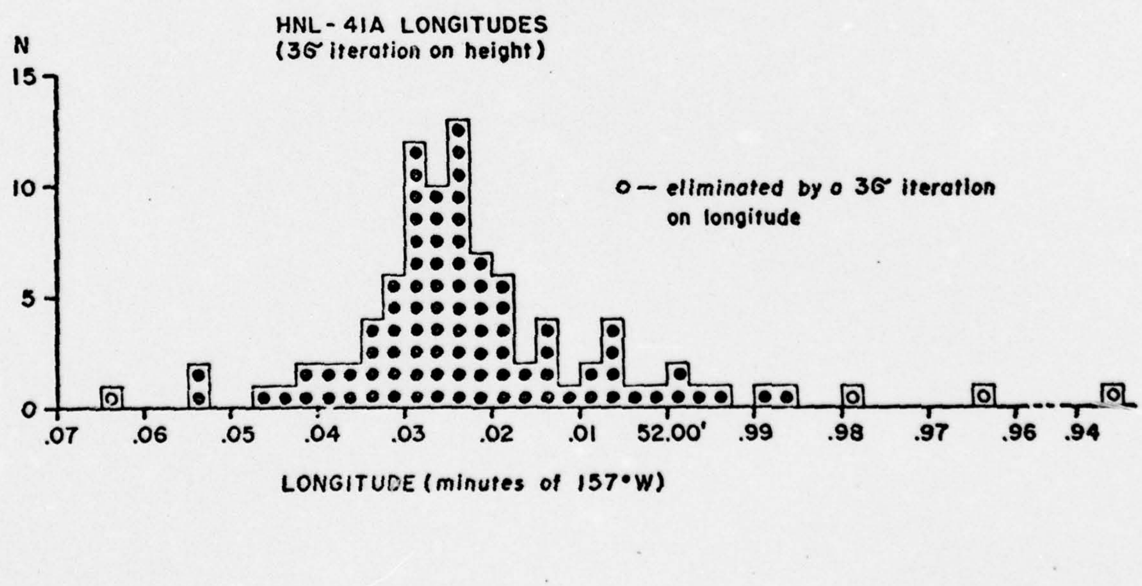

HNL-41A LONGITUDES
(3G iteration on height)
N
15
10
5
0
o — eliminated by a 3G iteration
on longitude
.07
.06
.05
.04
.03
.02
.01
52.00'
.99
.98
.97
.96
.94
LONGITUDE (minutes of 157°W)

FIG. 5

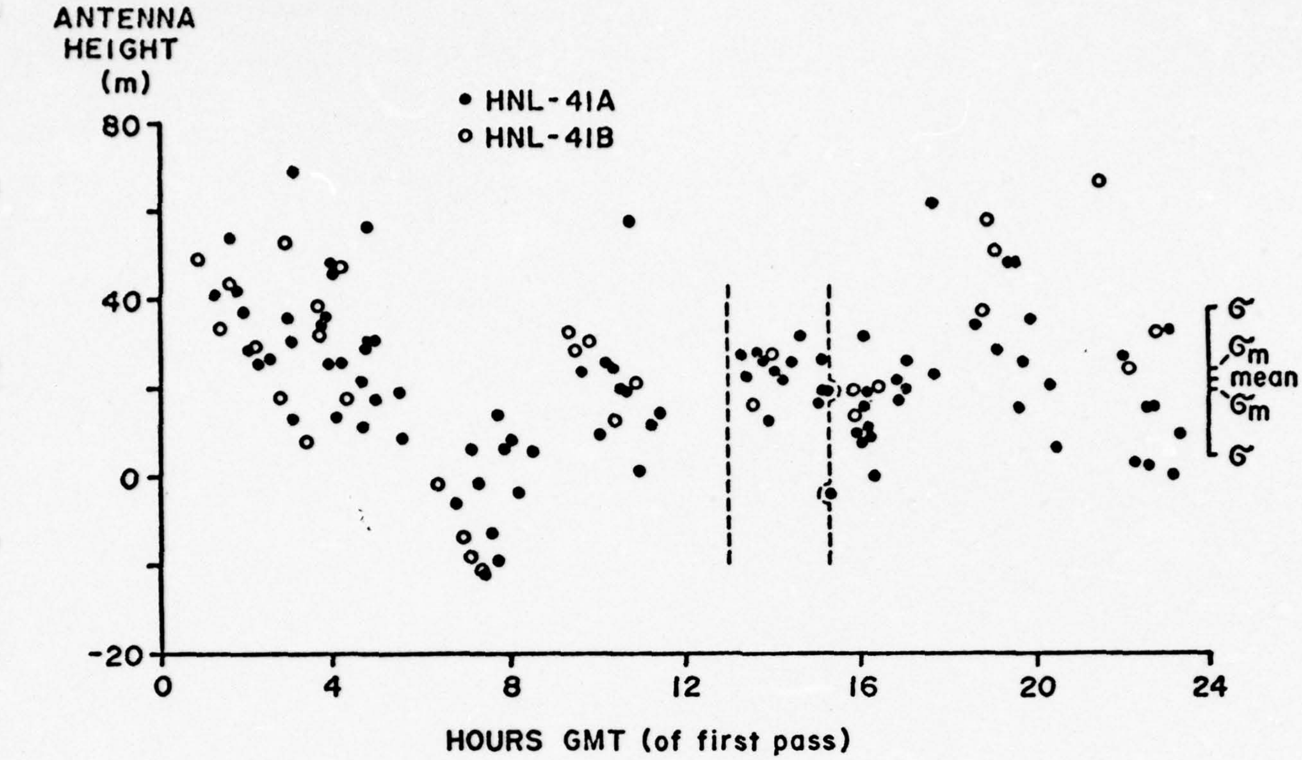

ANTENNA
HEIGHT
(m)
• HNL-41A
o HNL-41B
80
40
0
-20
0
4
8
12
16
20
24
σ
σm
mean
σm
σ
HOURS GMT (of first pass)

FIG. 6

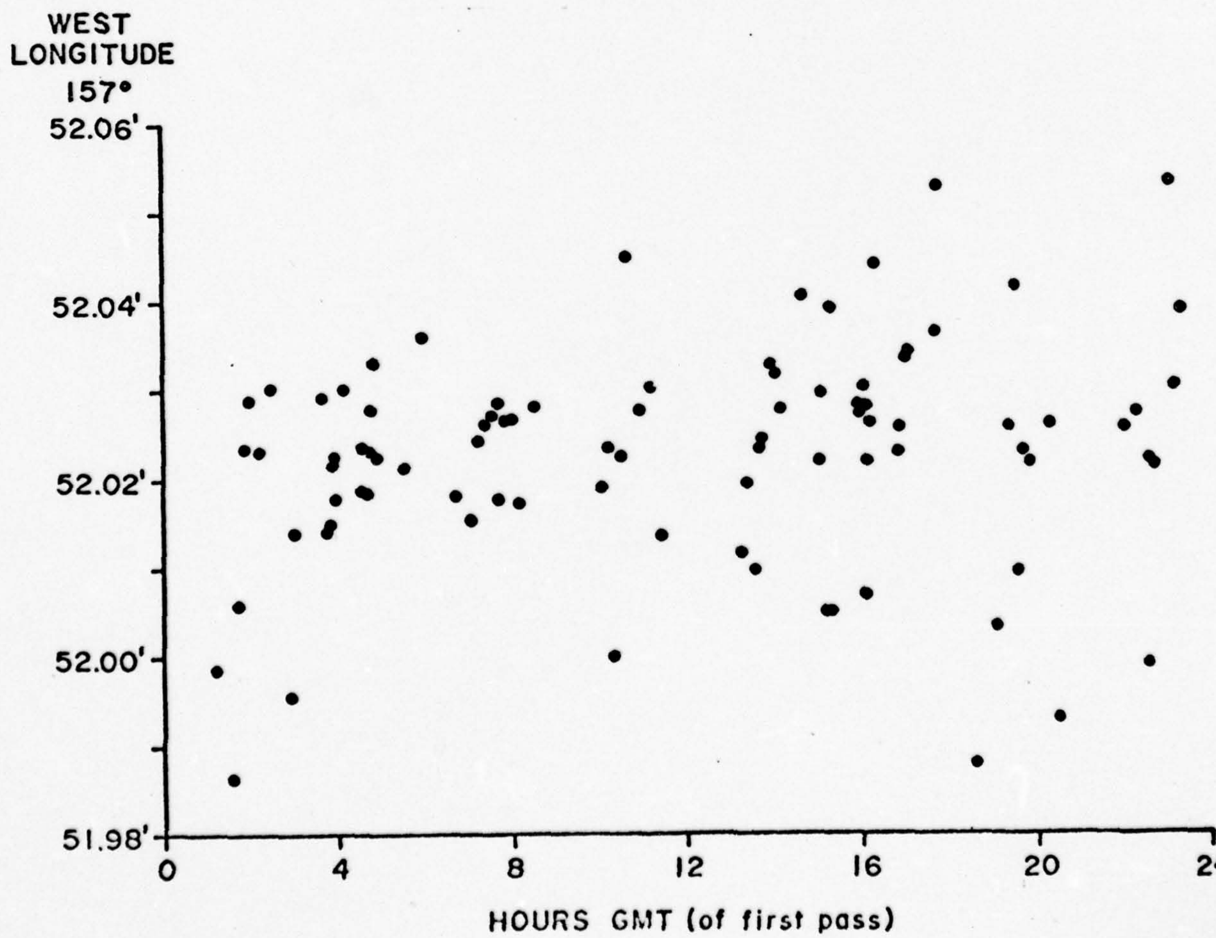
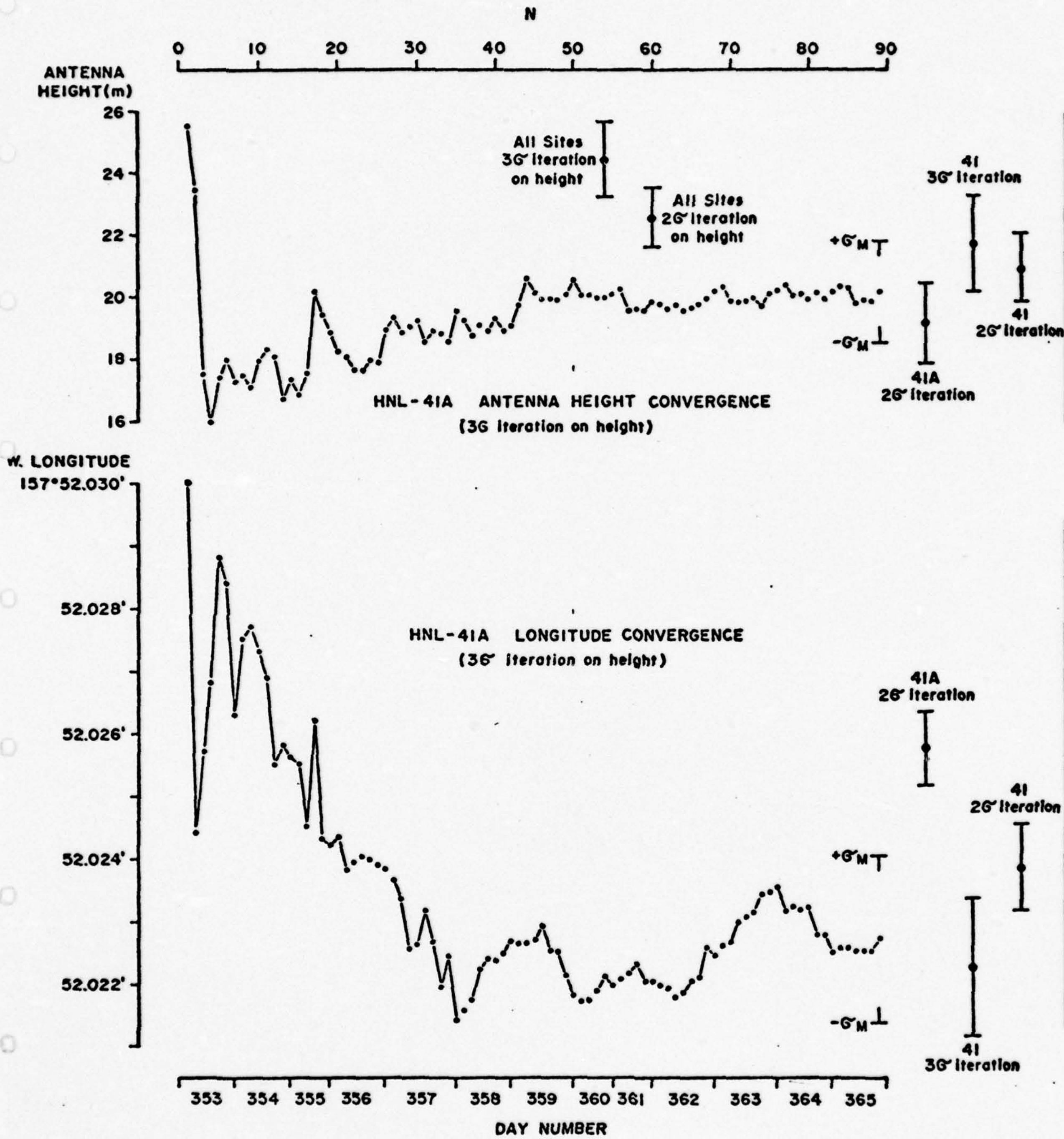
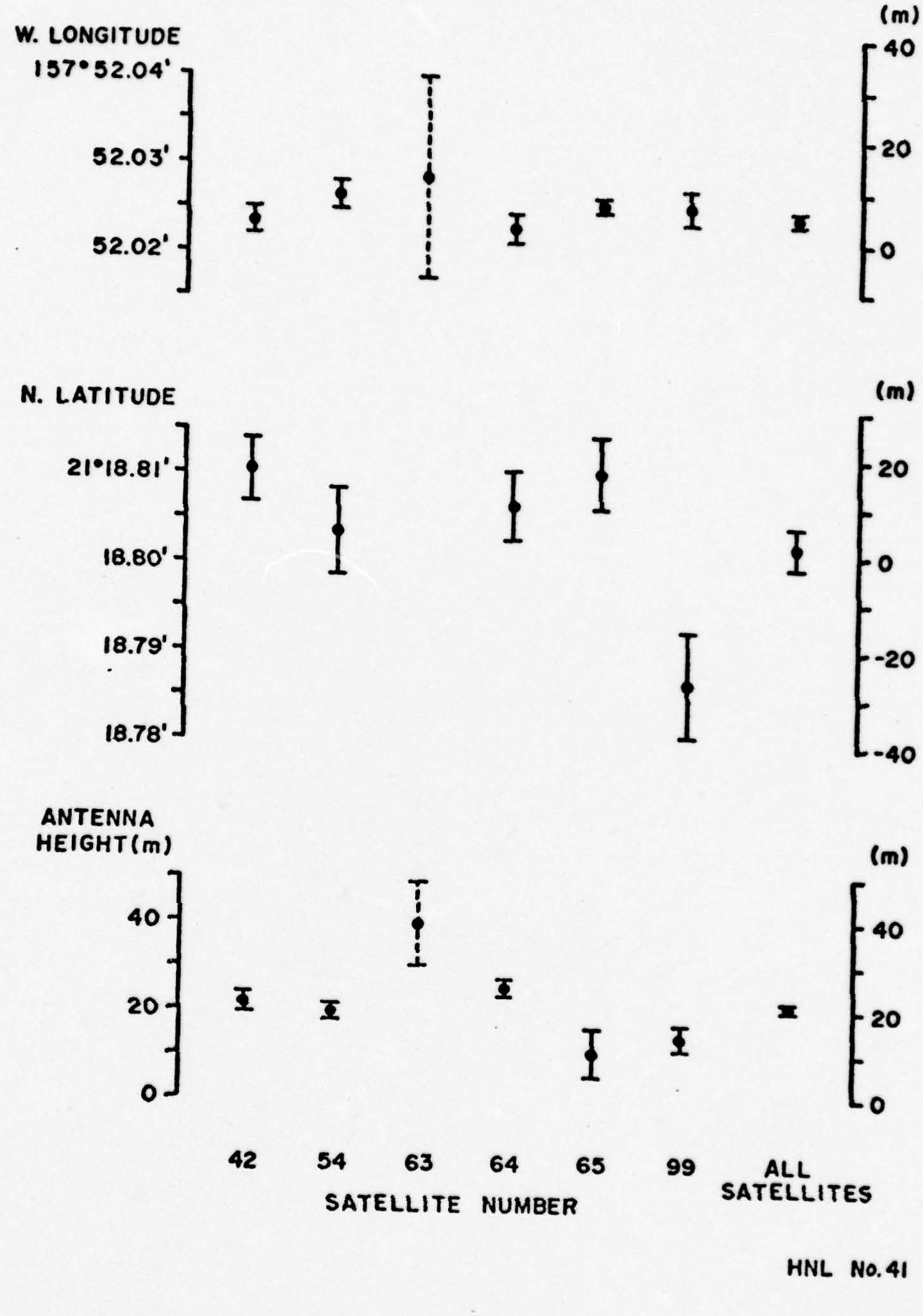

WEST
LONGITUDE
157°
52.06'
52.04'
52.02'
52.00'
51.98'
0
4
8
12
16
20
24
HOURS GMT (of first pass)

FIG. 7



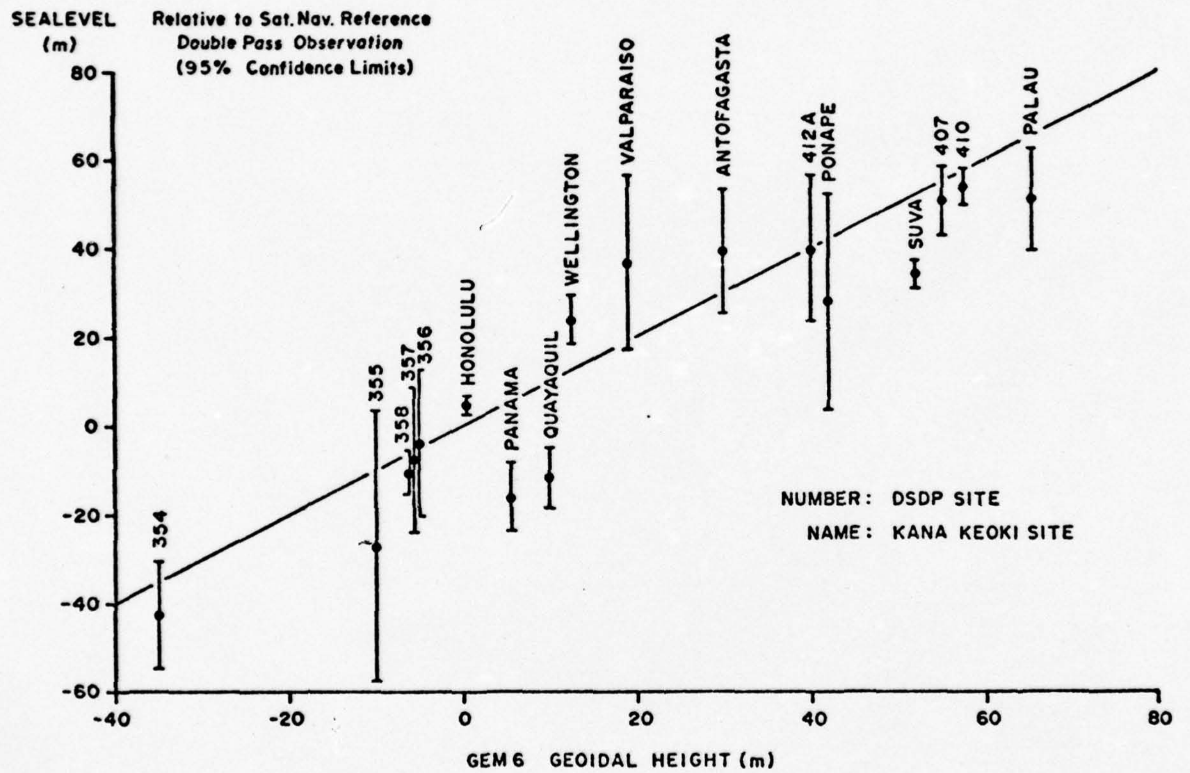
N
ANTENNA HEIGHT(m)
(m)
All Sites 3σ iteration on height
All Sites 2σ iteration on height
41 3σ iteration
41 2σ iteration
41A 2σ iteration
+σM
-σM
HNL-41A ANTENNA HEIGHT CONVERGENCE
(3σ iteration on height)
W. LONGITUDE
157°52.030'
52.028'
52.026'
52.024'
52.022'
HNL-41A LONGITUDE CONVERGENCE
(3σ iteration on height)
41A 2σ iteration
41 2σ iteration
41 3σ iteration
353 354 355 356 357 358 359 360 361 362 363 364 365
DAY NUMBER

FIG. 8



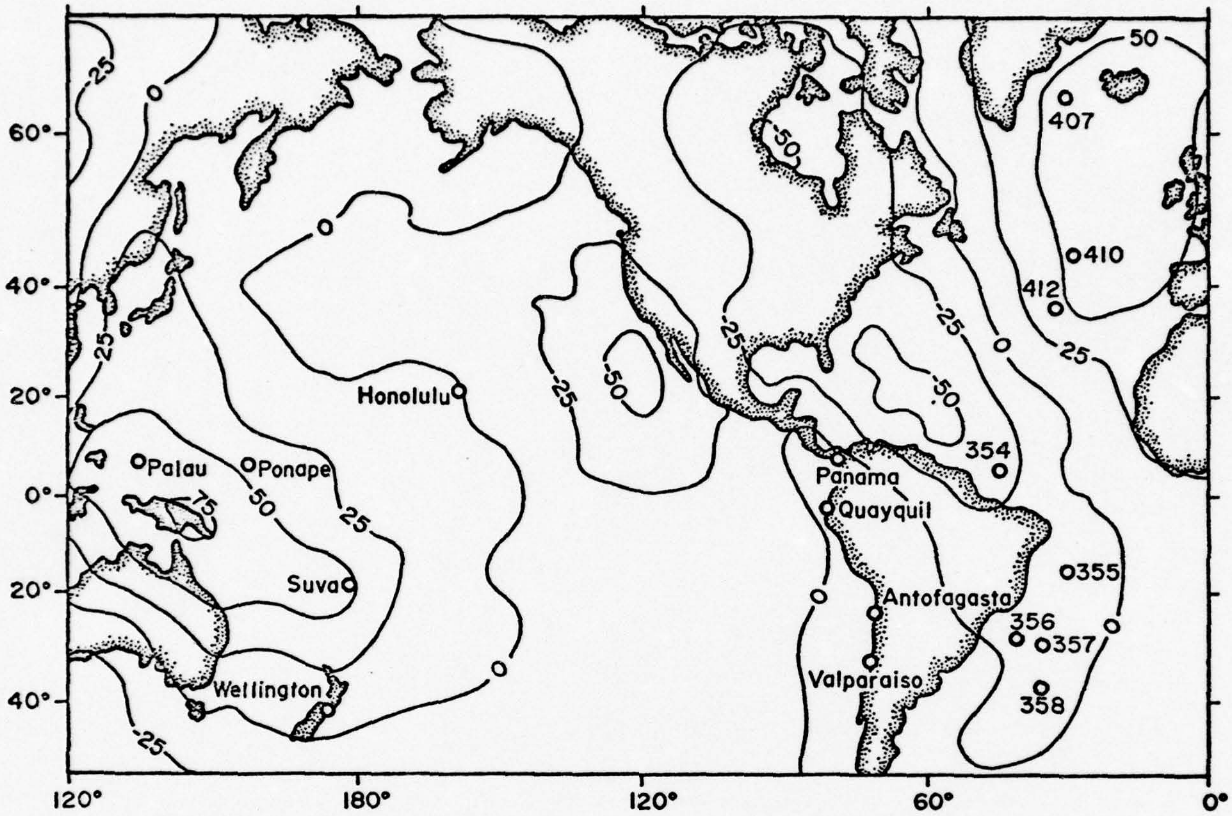
W. LONGITUDE
157°52.04'
52.03'
52.02'
(m)
40
20
0
N. LATITUDE
21°18.81'
18.80'
18.79'
18.78'
(m)
20
0
-20
-40
ANTENNA HEIGHT (m)
40
20
0
(m)
40
20
0
42
54
63
64
65
99
ALL SATELLITES
SATELLITE NUMBER
HNL No.41

FIG. 9



SEALEVEL (m)
Relative to Sat. Nav. Reference
Double Pass Observation
(95% Confidence Limits)
80
60
40
20
0
-20
-40
-60
354
355
358
357
356
HONOLULU
PANAMA
QUAYAQUIL
WELLINGTON
VALPARAISO
ANTOFAGASTA
412A
PONAPE
SUVA
407
410
PALAU
NUMBER: DSDP SITE
NAME: KANA KEOKI SITE
-40
-20
0
20
40
60
80
GEM 6 GEOIDAL HEIGHT (m)

FIG. 10



KANA KEOKI AND DSDP SEA LEVEL SITES

FIG. 11

APPENDIX

APPENDIX

Description

The Appendix contains all computer output plots to support the data presented in Tables 2 through 6. For each site and selection criterion two plots are generated. The first plot shows all double pass determinations, using selection criteria based on the satellite navigator output such as elevation angle, number of symmetric Doppler count intervals and a particular satellite or number of iterations required by the satellite navigator to obtain the single pass fix.

The second plot shows the remaining double pass determinations after iterations that reject double pass results outside a specified multiple of the standard deviation, usually 3σ or 2σ. If a third plot from a site is included, the nσ iteration limit is narrower (2σ) than on the second plot (3σ). These iteration limits are indicated on the bottom line of the plot. If a () appears with the iteration limit, no double passes have been disregarded and therefore the plot is identical to the first one. In such a case the first one is not presented.

With each two plots generated comes a computer output print. Only one example of such an output print is given in Table 1A through 1D for a 2σ iteration. For more details refer to the text.

The bottom line of each plot contains the site identification, initialized antenna height and, if applicable, the iteration limits and minimum number of symmetric Doppler counts.

General order of plots (identification by bottom line) :

Group I : includes all Kana Keoki (Pacific harbor) sites, in numerical order by increasing site numbers, where all double passes with elevation angles between 5^{o} and 75^{o} and up to five iterations on the satellite navigator and no restrictions on the actual number or the symmetry of the Doppler counts have been imposed. Rejection of double pass results on a 3σ and 2σ basis was carried out.

Group II : follows Group I and includes the DSDP sites (open Atlantic Ocean). The output plots are ordered by increasing site numbers. Selection criteria are the same as in Group I. Rejection was carried out on a 2σ basis only.

Group III : This group has selected sites from Group I to show the influence of selection for increasing number of symmetric Doppler count intervals. The other selection criteria are as in Group I and Group II (refer to text and Table 3B, 4B, and 5). The sequence of plots by site, selection and rejection criteria is as follows. Honolulu sites 25, 26, 38, 39A and B, for six or more symmetric Doppler counts (D.C.>5), 3σ iterations : sites 40 and 41, increasing number of Doppler counts, 3σ iterations.

Suva (12, 13, 14, 28, 29)

Callao (16, 17, (A), (D))

Palau (11)

Wellington (15)

Quayaquil (20 and 32)

Panama (47)

(all with six or more (D.C. > 5) and nine or more (D. C. > 8) symmetric Doppler counts and 3σ iterations)

Group IV: This last group shows the influence of different satellites on position and height coordinates (refer to text and Table 3C and 4C). The sequence of plots is : Honolulu (#41), by increasing satellite identification numbers (which appear in the plots above the line connecting the two x,y positions of a double pass) and Suva (#14), by increasing satellite identification numbers. Selection criteria are as in Group I. Rejection by 3σ and 2σ iterations for Honolulu and 3σ for Suva.

The results for the computations are printed in the three top lines for the mean, standard deviation (σ), and the standard deviation of the mean (σ_m) of latitude, longitude, and antenna height.

Longitude is E or W as indicated on the right-hand side of the X axis.

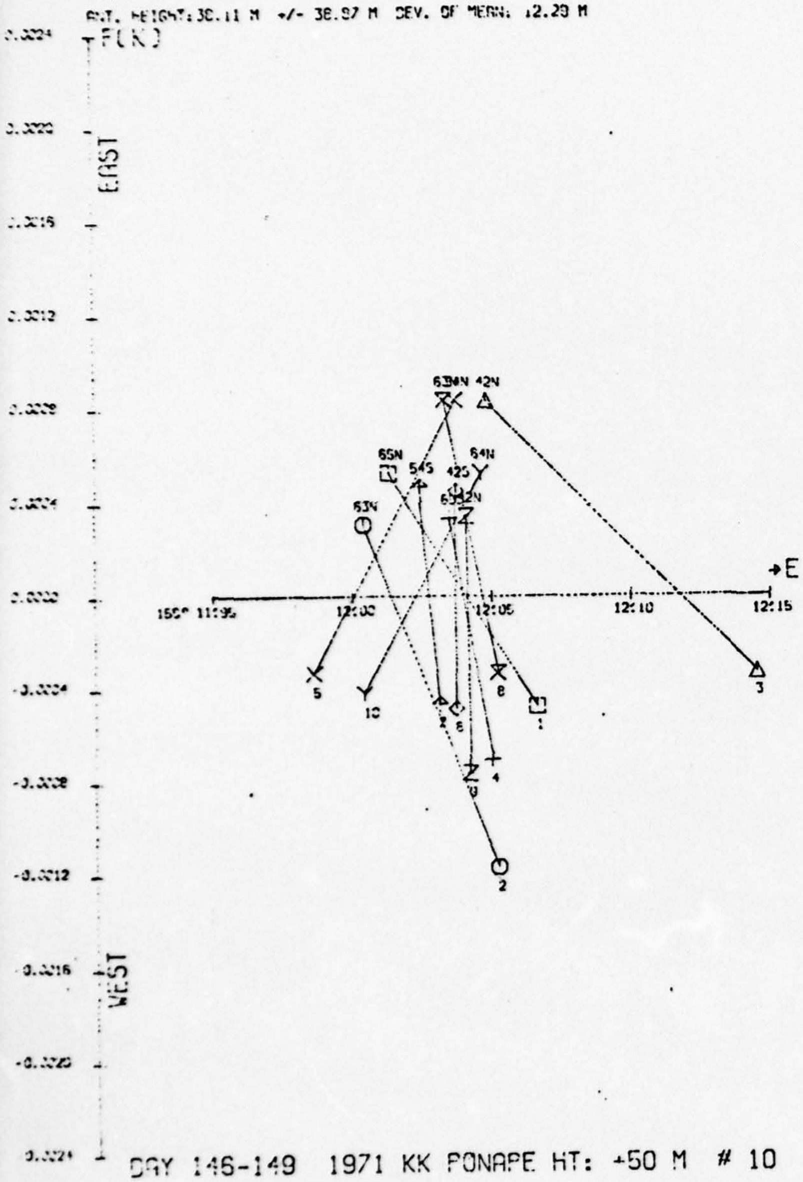
Latitude is N-positive or S-negative.

Antenna height is calculated from double pass correction added to the initialized height (the latter is indicated on the bottom line of each plot).

Group I

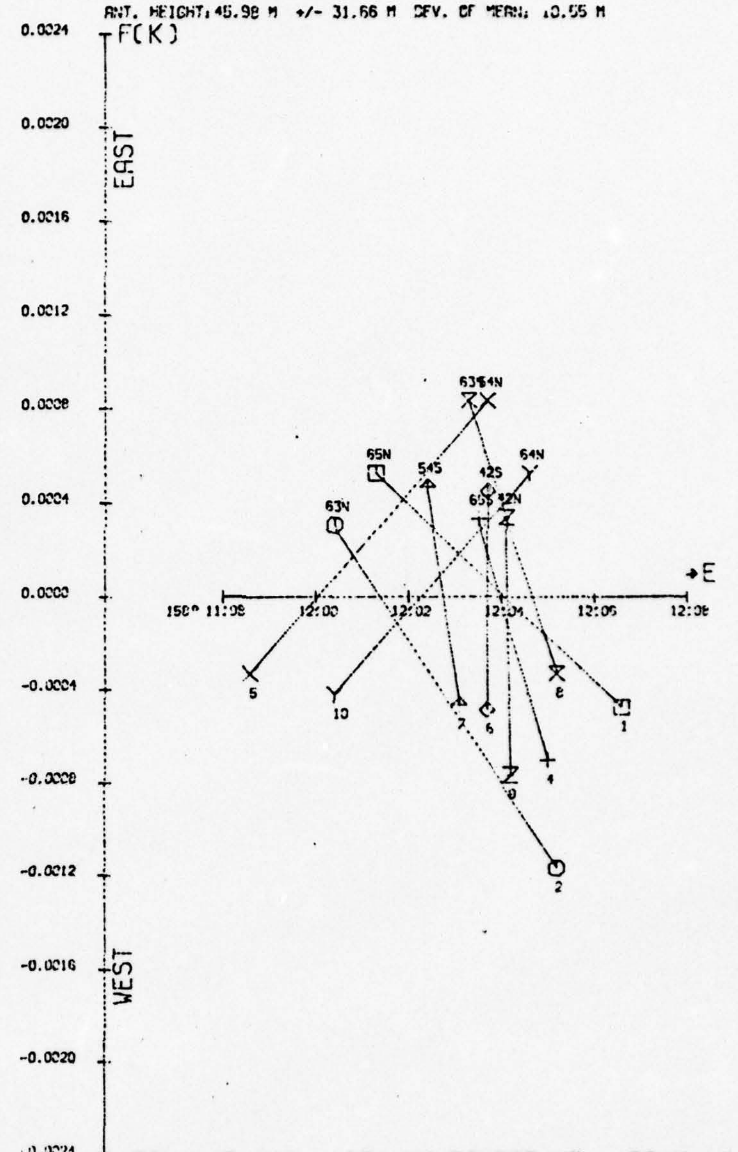
35 78

LAT.: 6° 55'.7527 +/- 0'.0416 (77.06 M) DEV. OF MEAN: 0'.0093 (17.23 M)
LONG. 158° 12'.0387 +/- 0'.0311 (57.26 M) 0'.0098 (18.11 M)
ANT. HEIGHT: 38.11 M +/- 38.97 M DEV. OF MEAN: 12.29 M



DAY 146-149 1971 KK PONAPE HT: +50 M # 10 (3σ)

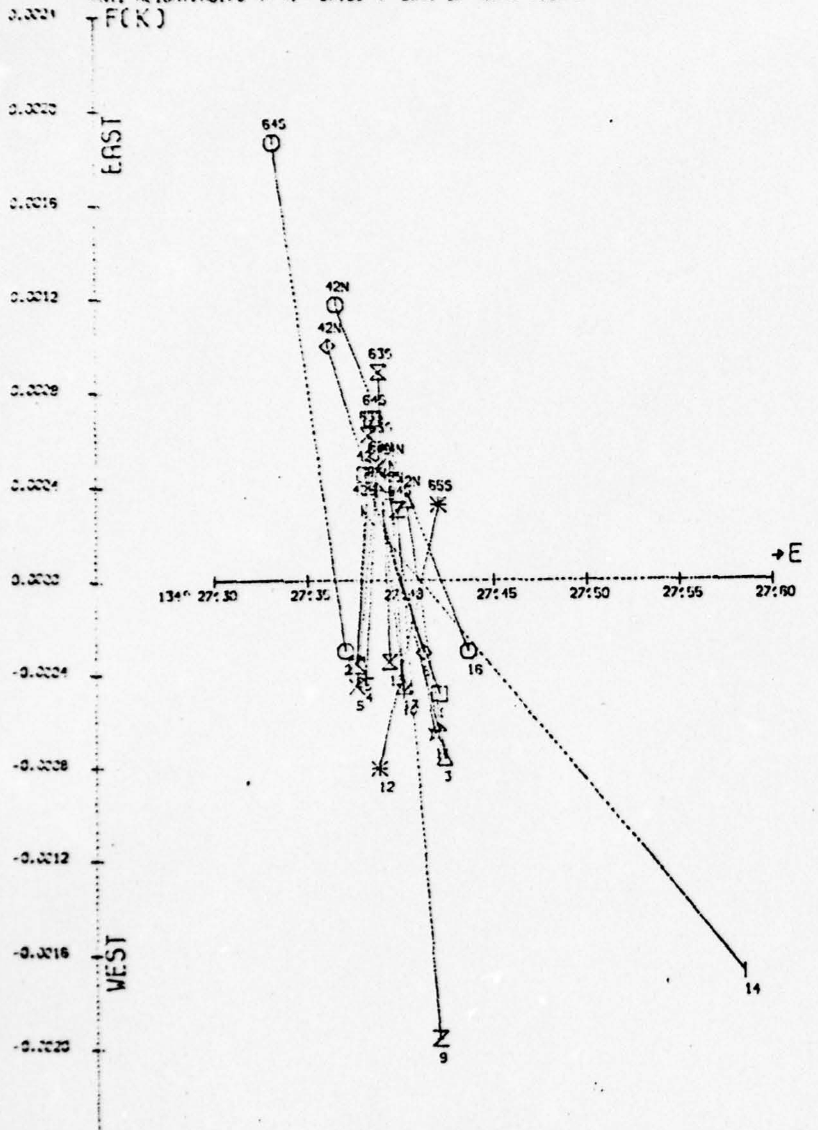
LAT.: 6° 58'.7471 +/- 0'.0333 (61.72 M) DEV. OF MEAN: 0'.0078 (14.55 M)
LONG. 158° 12'.0300 +/- 0'.0152 (27.98 M) 0'.0051 (9.33 M)
ANT. HEIGHT: 45.98 M +/- 31.66 M DEV. OF MEAN: 10.55 M



DAY 146-149 1971 KK PONAPE HT: +50 M # 10 2σ

36

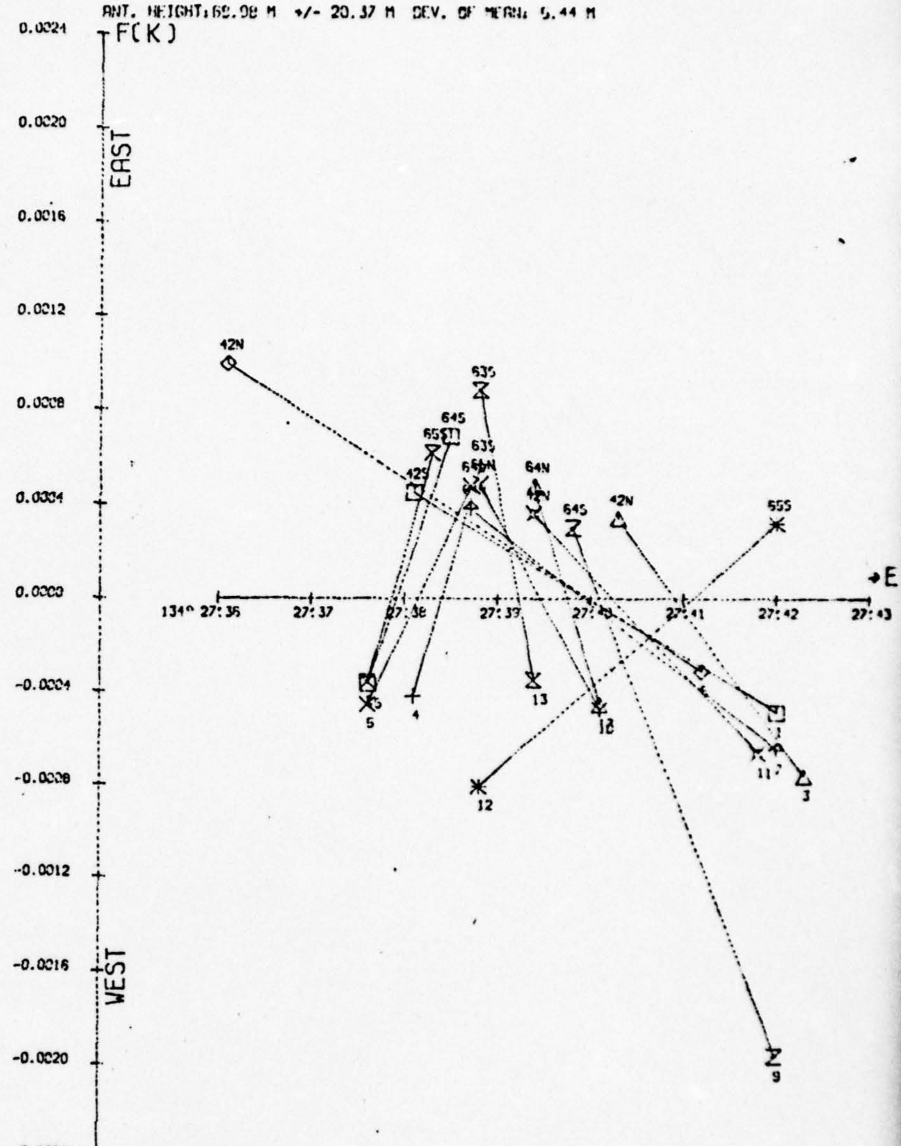
LAT.. 7° 19:9089 +/- 0:0594 (110.14 M) DEV. OF MEAN: 0:0102 (18.89 M)
LONG.. 134° 27:3760 +/- 0:0143 (26.36 M) 0:0035 (6.39 M)
ANT. HEIGHT: 60.73 M +/- 30.08 M DEV. OF MEAN: 7.30 M



DAY 167-171 1971 KK PALAU HT: +78 M # 11 (3σ)

80

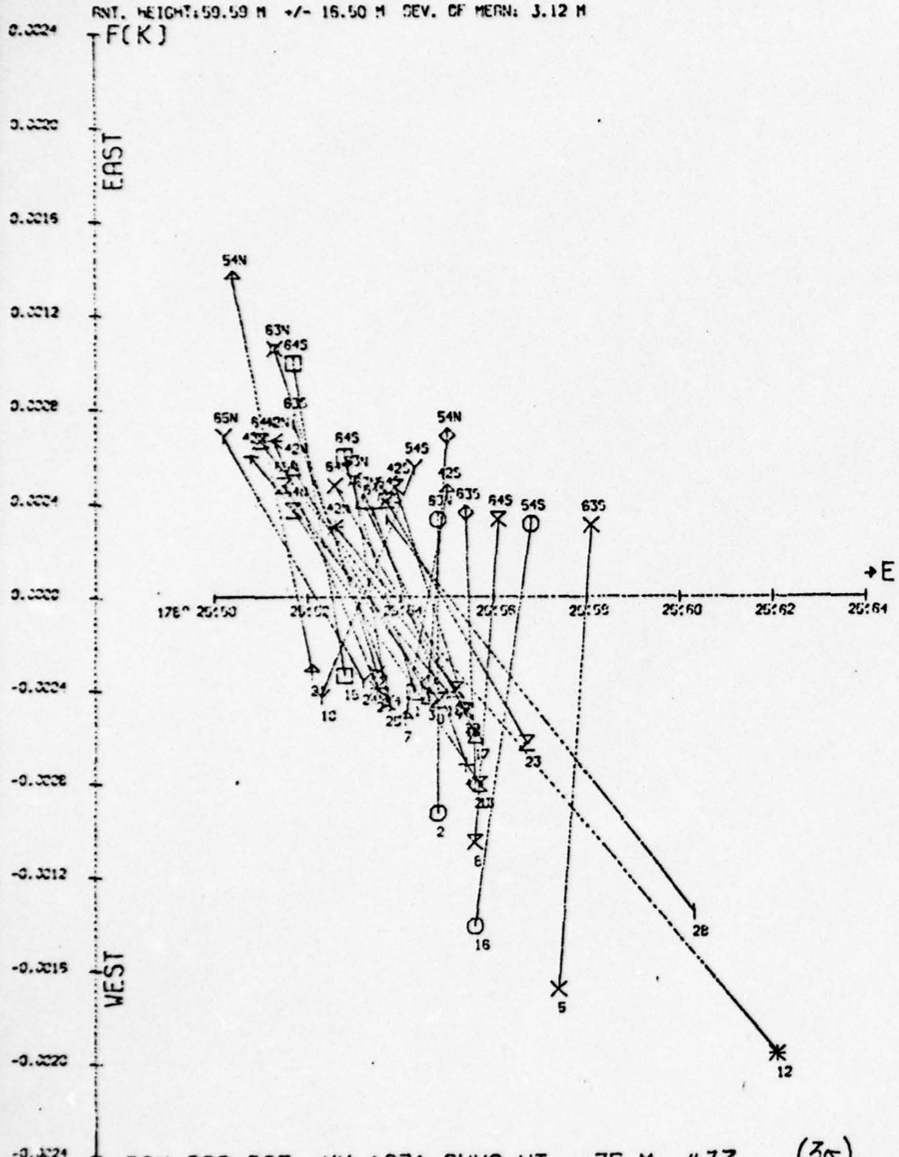
LAT.: 7° 19:9218 +/- 0:0182 (33.79 M) DEV. OF MEAN: 0:0034 (6.33 M)
LONG.. 134° 27:3945 +/- 0:0106 (19.43 M) 0:0028 (5.13 M)
ANT. HEIGHT: 69.98 M +/- 20.37 M DEV. OF MEAN: 5.44 M



DAY 167-171 1971 KK PALAU HT: +78 M # 11 2σ

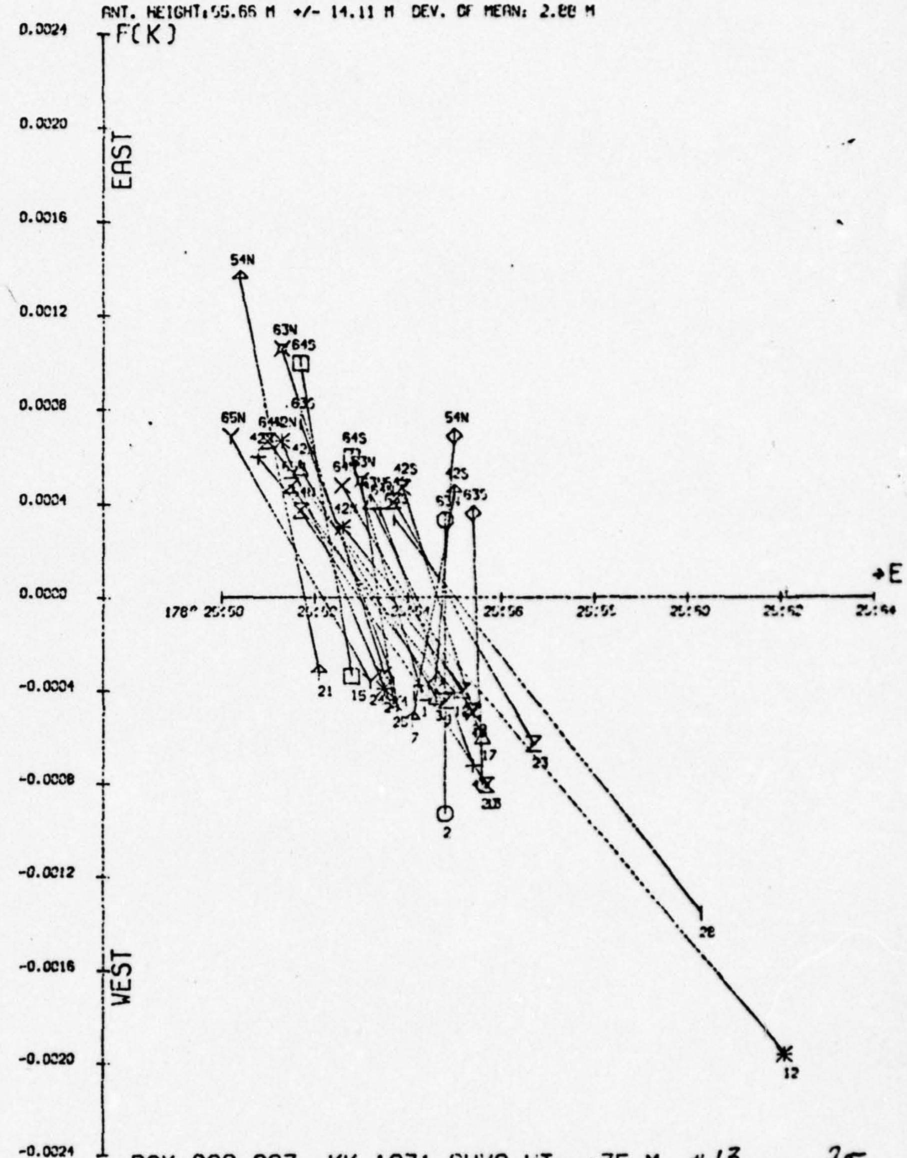
130 127

LAT.. -18° 7.7771 +/- 0.0241 (44.70 M) DEV. OF MEAN: 0.0032 (5.97 M)
LONG. 178° 25.5402 +/- 0.0137 (24.14 M) 0.0026 (4.56 M)
ANT. HEIGHT:59.59 M +/- 16.50 M DEV. OF MEAN: 3.12 M



DAY 202-207 KK 1971 SUVA HT: +75 M #13 (3σ)

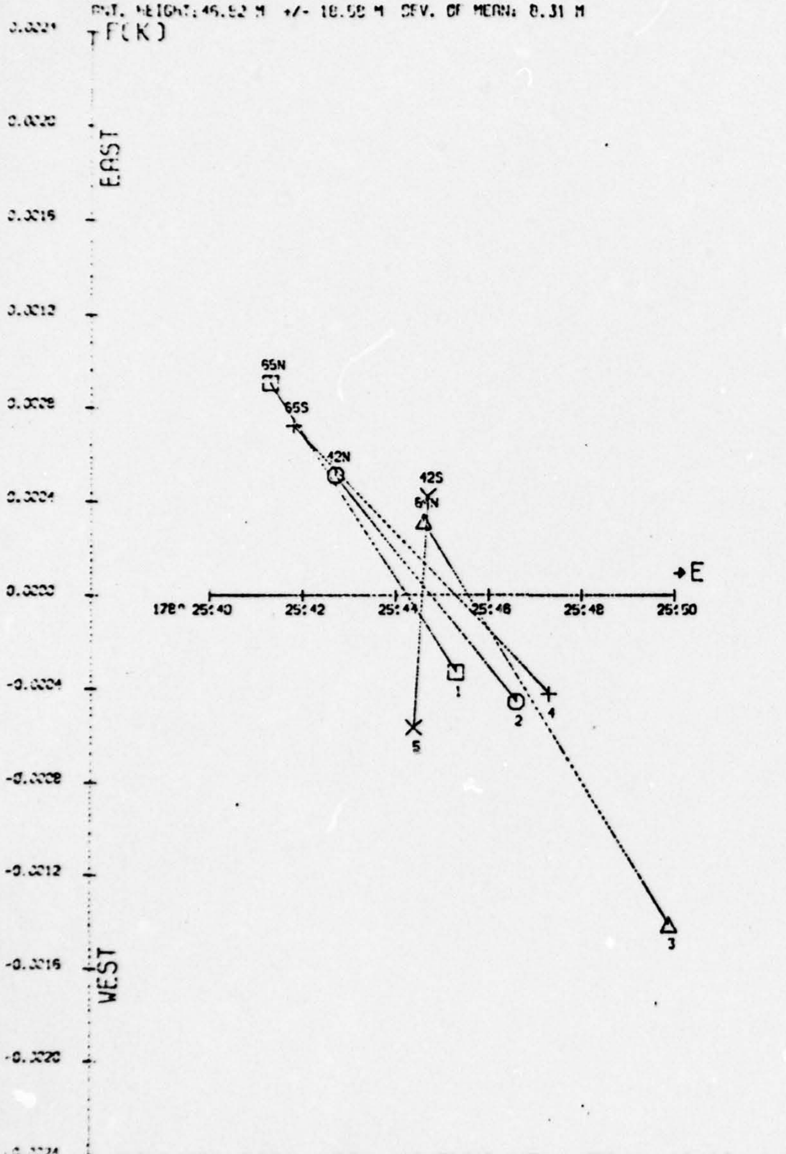
LAT.: -18° 7.7793 +/- 0.0247 (45.79 M) DEV. OF MEAN: 0.0036 (6.51 M)
LONG. 178° 25.5370 +/- 0.0096 (16.98 M) 0.0020 (3.47 M)
ANT. HEIGHT:55.66 M +/- 14.11 M DEV. OF MEAN: 2.88 M



DAY 202-207 KK 1971 SUVA HT: +75 M #13 2σ

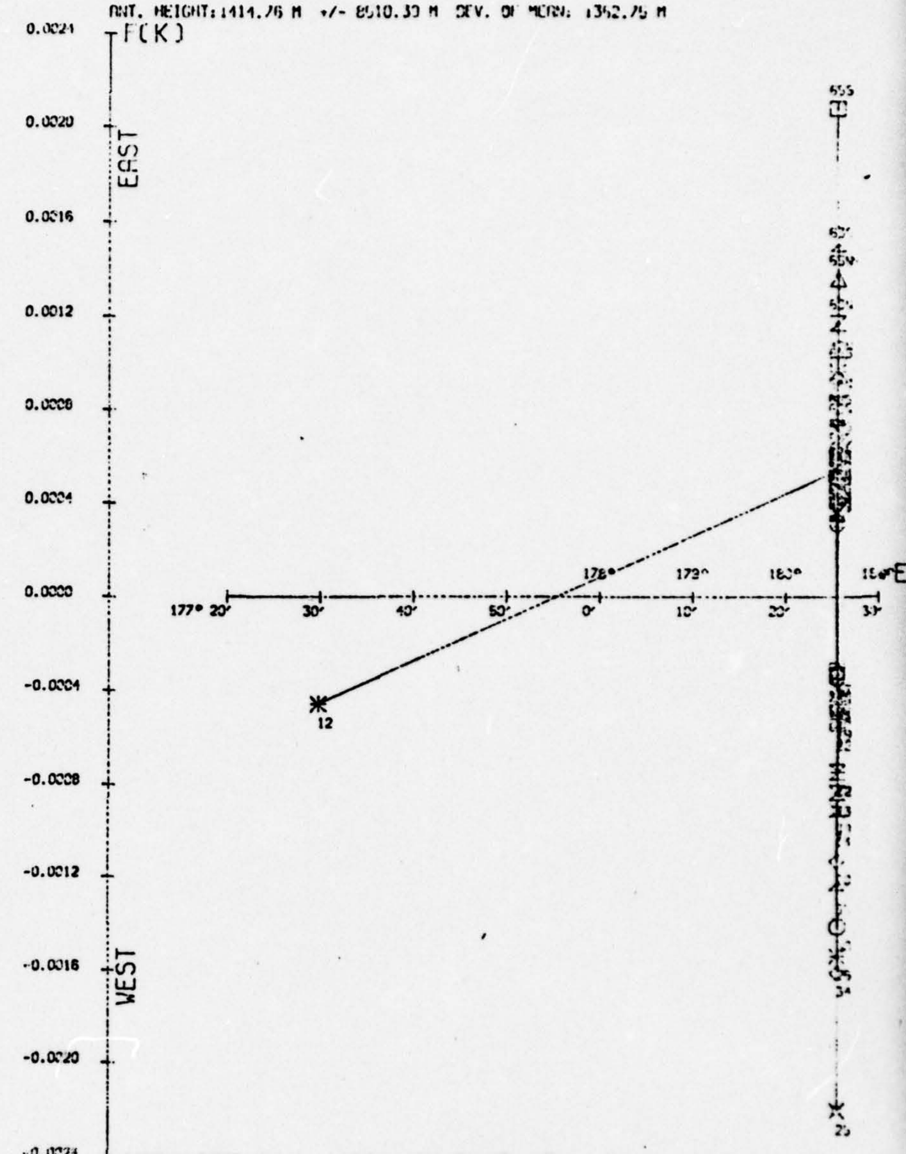
37 1, 38

LAT.. -18° 7:0382 +/- 0:0166 (30.83 M) DEV. OF MEAN: 0:0053 (9.75 M)
LONG. 178° 25:4488 +/- 0:0054 (9.46 M) 0:0024 (4.23 M)
ANT. HEIGHT: 46.52 M +/- 18.58 M DEV. OF MEAN: 8.31 M



DAY 201-202 1971 KK SUVA HT: +75 M # 12 (3σ)(2σ)

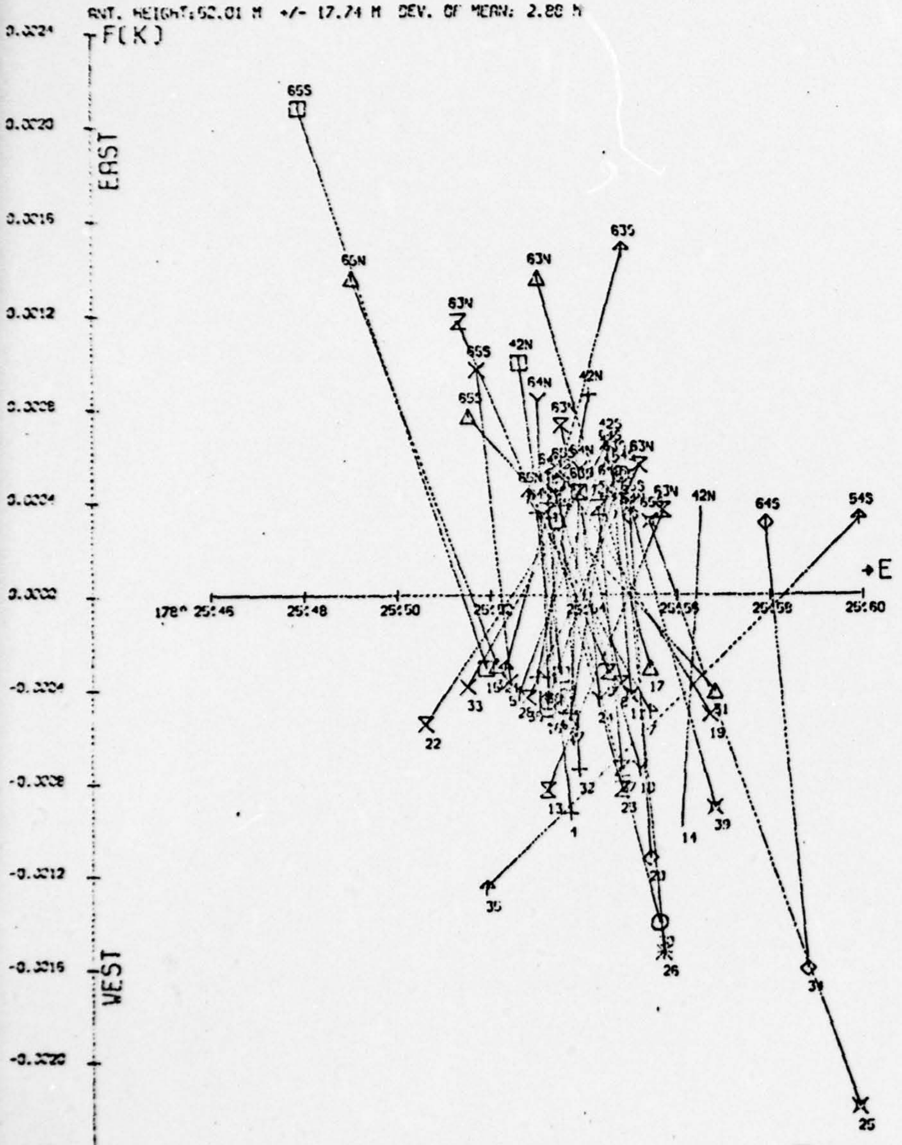
LAT.: -18° 8:1611 +/- 3:3363 (6204.07 M) DEV. OF MEAN: 0:3845 (712.56 M)
LONG.. 178° 24:7678 +/- 4:6255 (8408.38 M) 0:7727 (1430.03 M)
ANT. HEIGHT: 1414.76 M +/- 8510.33 M DEV. OF MEAN: 1362.75 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14

39

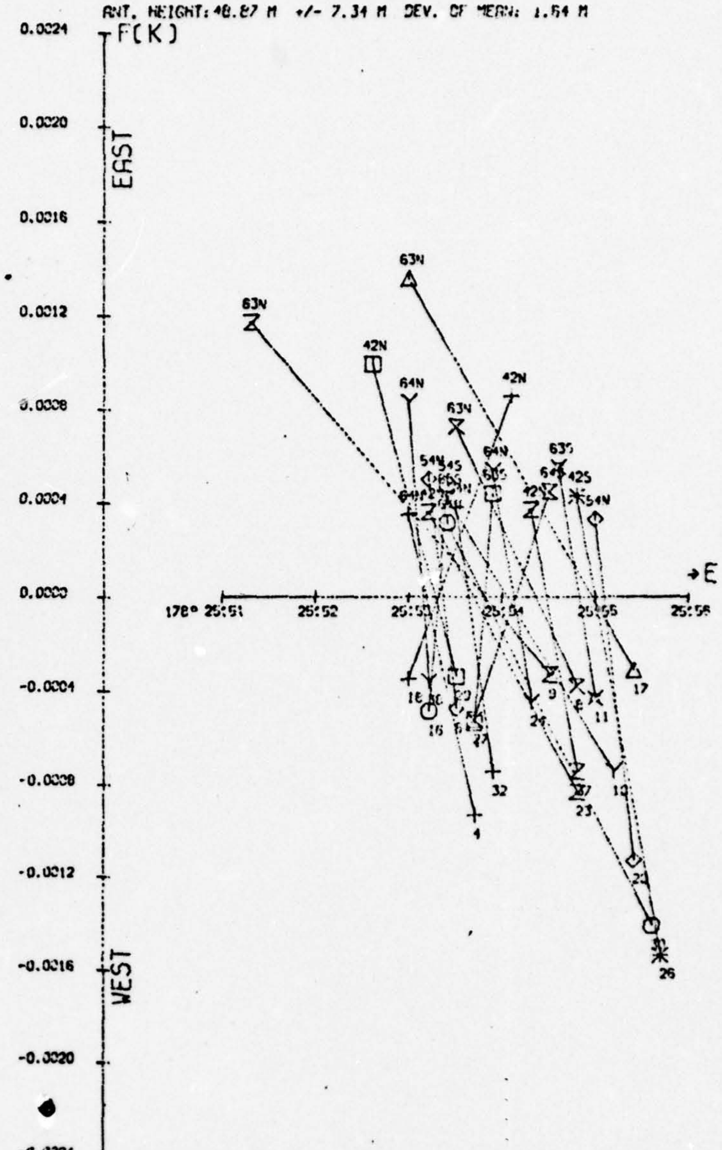
LAT.: -18° 7:7760 +/- 0:0315 (58.28 M) DEV. OF MEAN: 0:0036 (6.69 M)
LONG.. 178° 25:5405 +/- 0:0147 (25.86 M) 0:0024 (4.19 M)
ANT. HEIGHT: 52.01 M +/- 17.74 M DEV. OF MEAN: 2.88 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 3σ

8

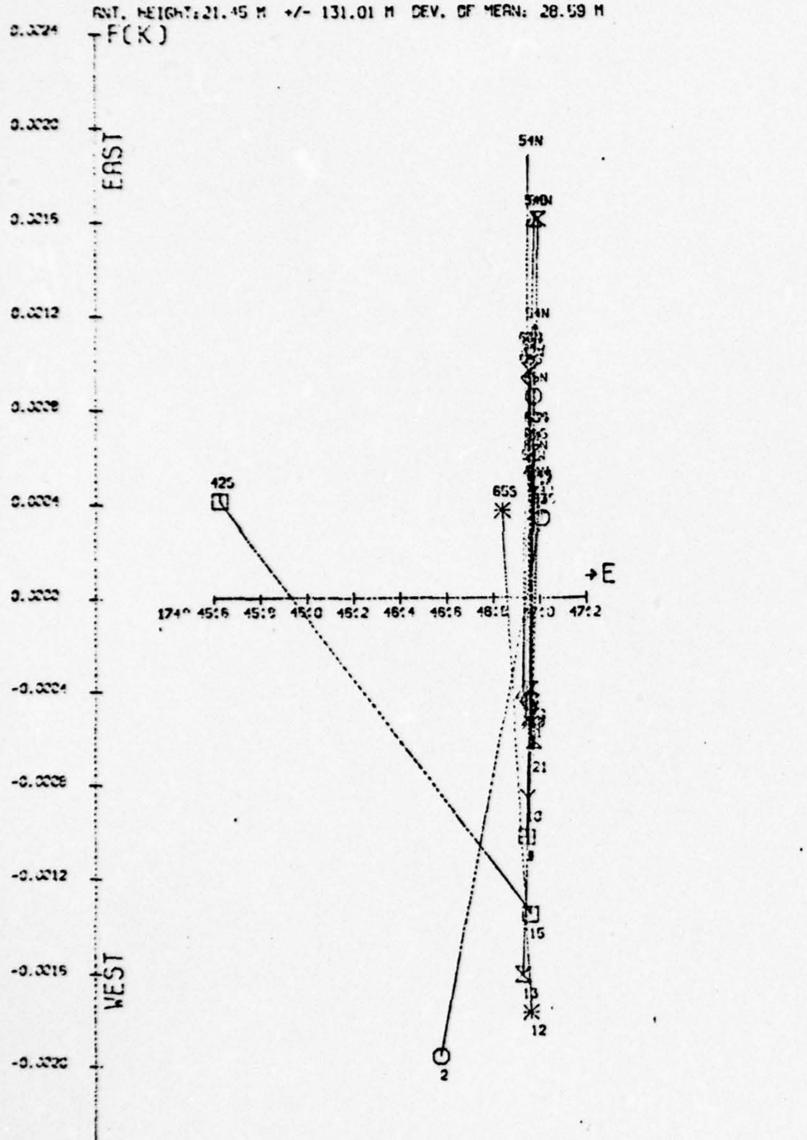
LAT.: -18° 7:7844 +/- 0:0291 (53.98 M) DEV. OF MEAN: 0:0046 (8.53 M)
LONG.. 178° 25:5391 +/- 0:0064 (11.23 M) 0:0014 (2.52 M)
ANT. HEIGHT: 48.87 M +/- 7.34 M DEV. OF MEAN: 1.54 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 2σ

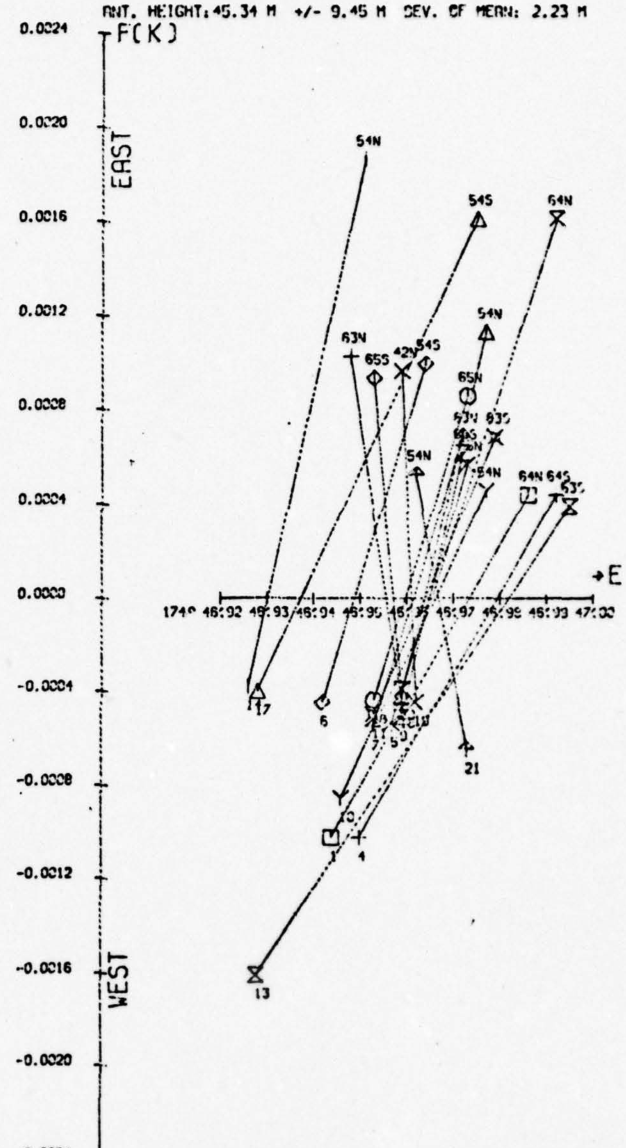
40

LAT.. -41° 16:9297 +/- 0:1795 (332.70 M) DEV. OF MEAN: 0:0277 (51.34 M)
LONG.. 174° 46:0056 +/- 0:2240 (311.98 M) 0:0489 (69.08 M)
ANT. HEIGHT: 21.45 M +/- 131.01 M DEV. OF MEAN: 28.59 M



DAY 241-244 1971 KK WELLINGTON HT: +35 M # 15

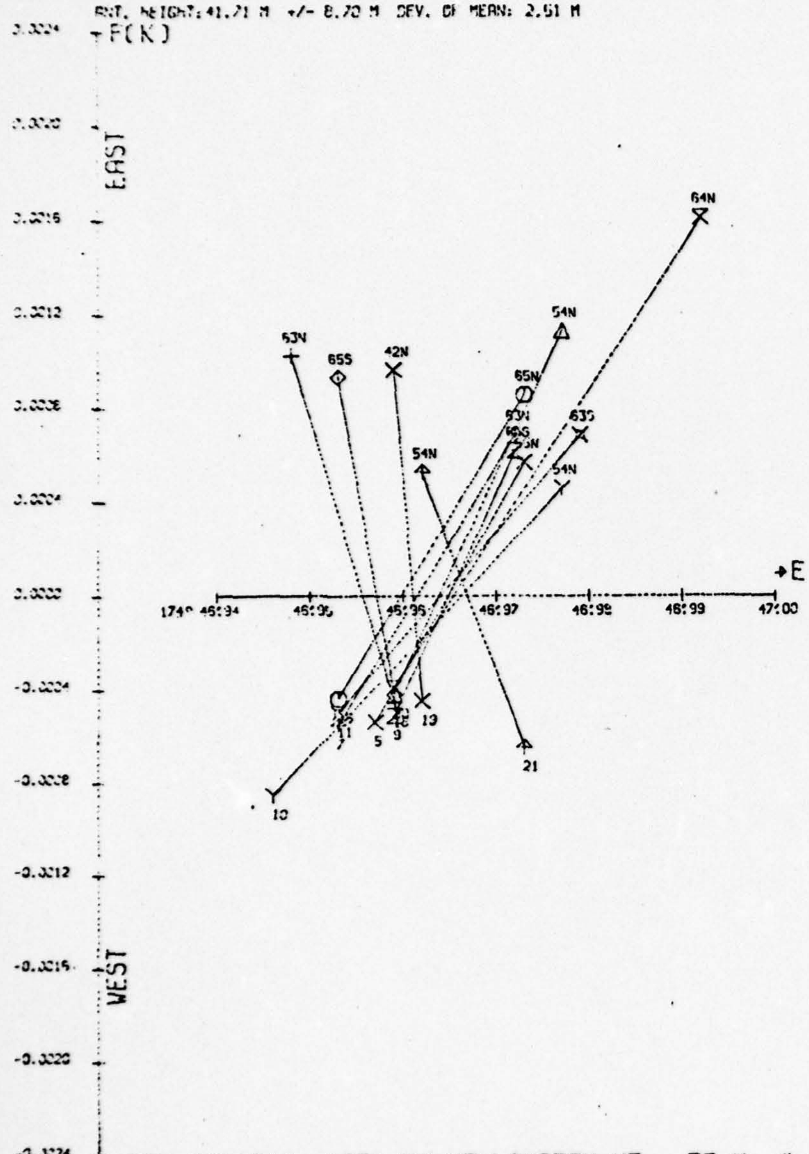
LAT.: -41° 16:9014 +/- 0:0110 (20.32 M) DEV. OF MEAN: 0:0018 (3.37 M)
LONG.. 174° 46:9612 +/- 0:0127 (17.72 M) 0:0030 (4.18 M)
ANT. HEIGHT: 45.34 M +/- 9.45 M DEV. OF MEAN: 2.23 M



DAY 241-244 1971 KK WELLINGTON HT: +35 M # 15

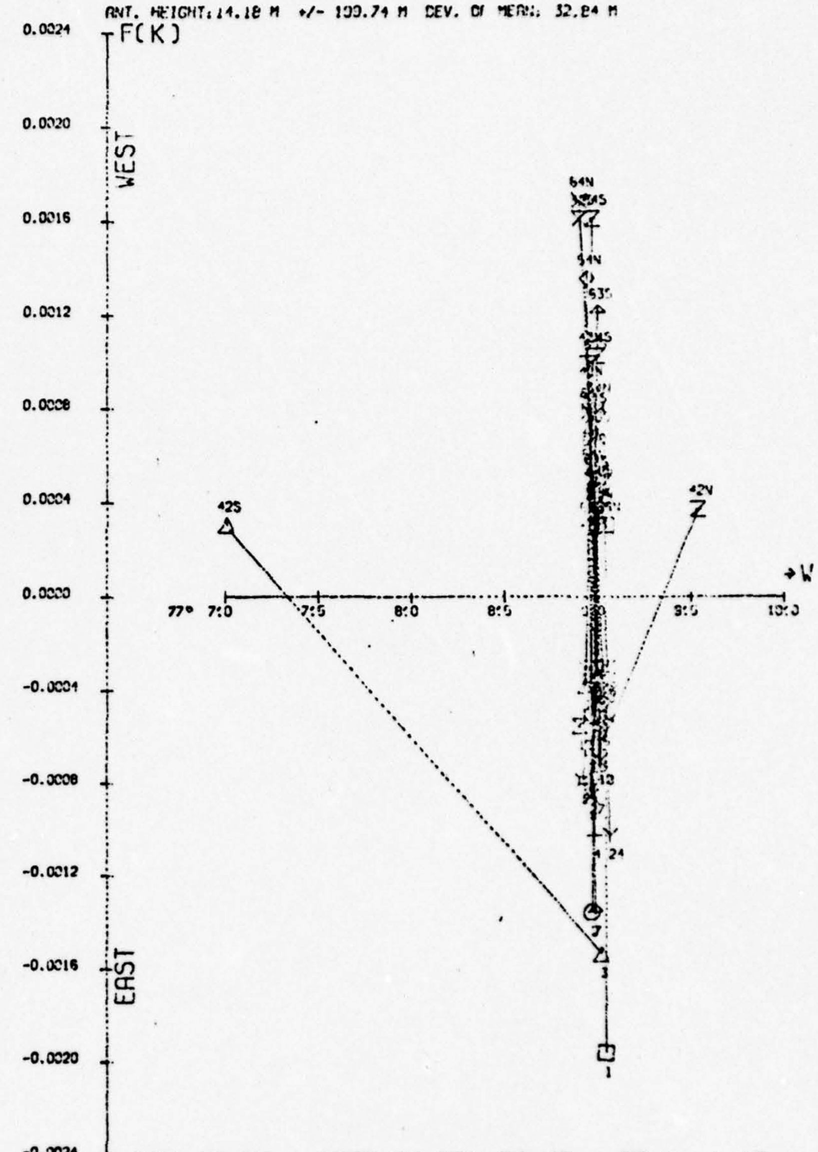
85 42

LAT.. -41° 15:9038 +/- 0:0085 (15.75 M) DEV. OF MEAN: 0:0017 (3.21 M)
LONG. 174° 46:9625 +/- 0:0035 (5.03 M) 0:0010 (1.45 M)
ANT. HEIGHT: 41.71 M +/- 8.70 M DEV. OF MEAN: 2.51 M



DAY 241-244 1971 KK WELLINGTON HT: +35 M # 15 20

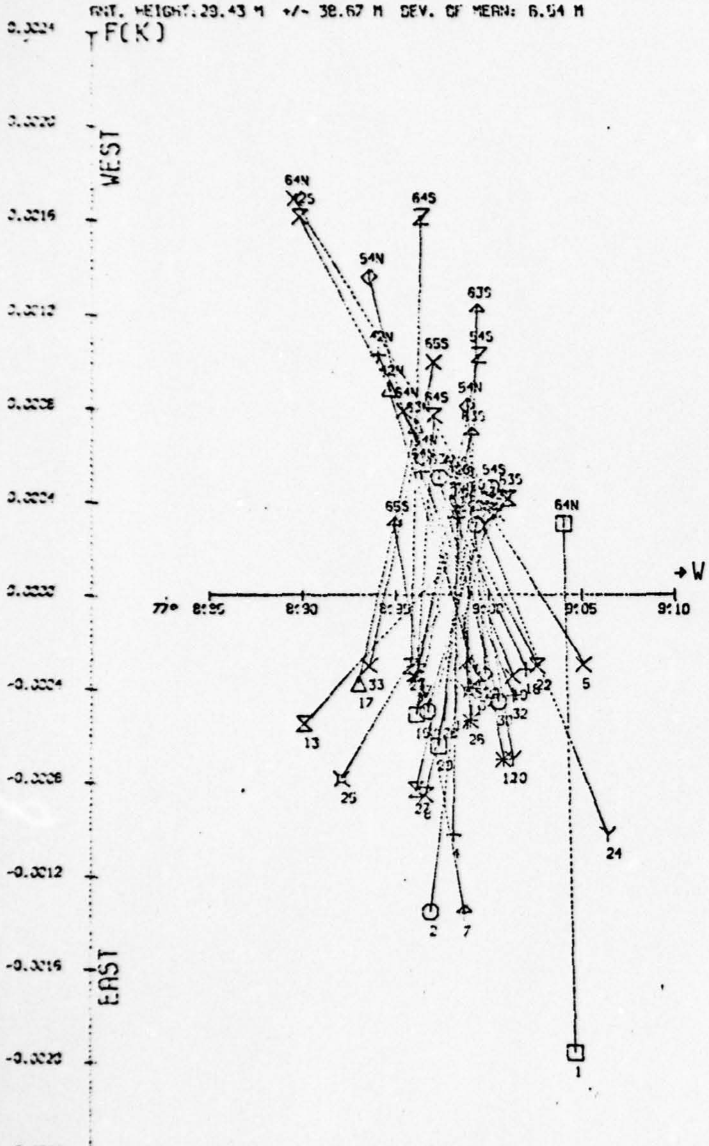
LAT.. -12° 3:3276 +/- 0:0614 (113.73 M) DEV. OF MEAN: 0:0071 (13.22 M)
LONG. 77° 8:9404 +/- 0:2793 (506.22 M) 0:0459 (83.22 M)
ANT. HEIGHT: 14.18 M +/- 199.74 M DEV. OF MEAN: 32.84 M



DAY 15-22 1972 KK CALLAO HT: +33 M # 16

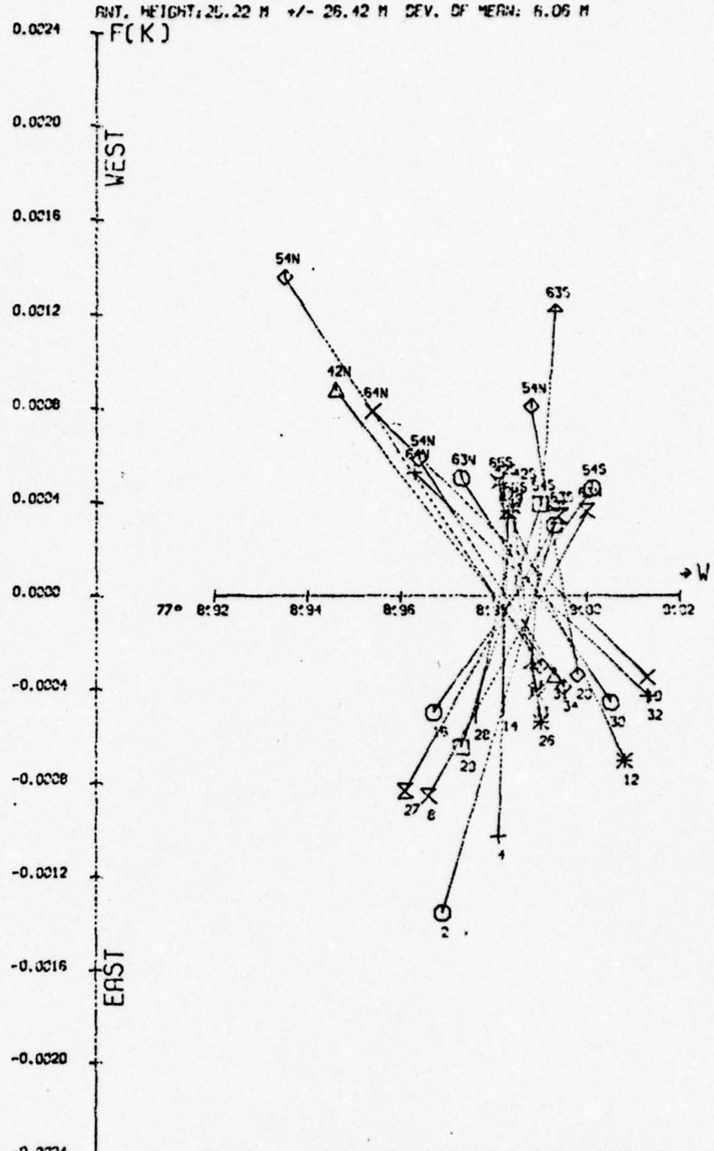
43

LAT.: -12° 3:3237 +/- 0:0580 (103.63 M) DEV. OF MEAN: 0:0067 (12.39 M)
LONG. 77° 8:9842 +/- 0:0200 (35.34 M) 0:0034 (6.14 M)
ANT. HEIGHT:29.43 M +/- 38.67 M DEV. OF MEAN: 6.54 M



DAY 15-22 1972 KK CALLAO HT: +33 M # 16 3σ

LAT.: -12° 3:3250 +/- 0:0259 (47.80 M) DEV. OF MEAN: 0:0042 (7.77 M)
LONG. 77° 8:9864 +/- 0:0047 (8.51 M) 0:0011 (1.95 M)
ANT. HEIGHT:25.22 M +/- 26.42 M DEV. OF MEAN: 6.06 M

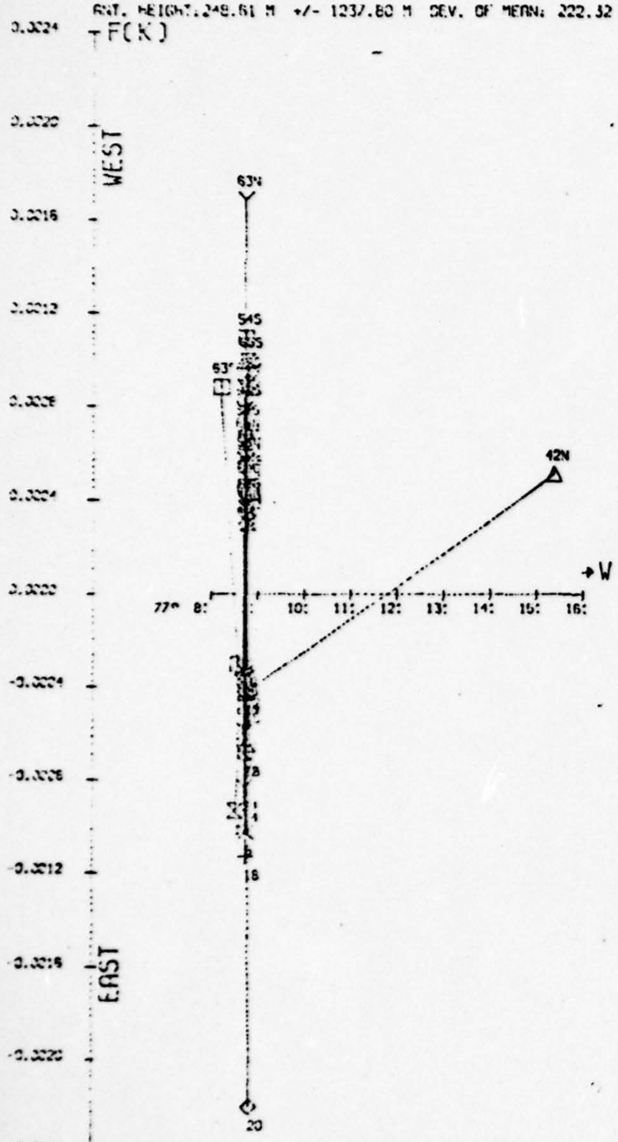


DAY 15-22 1972 KK CALLAO HT: +33 M # 15 2σ

8

41

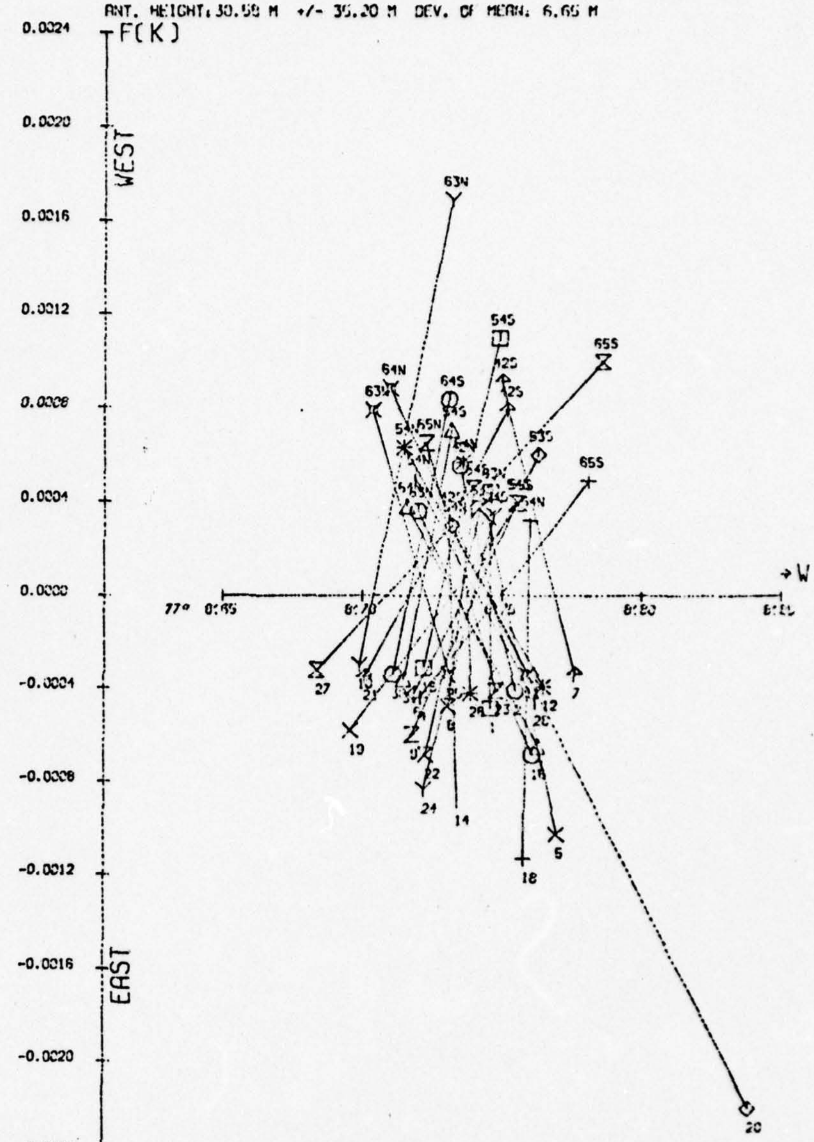
LAT.. -12° 2:0380 +/- 0:6748 (1250.53 M) DEV. OF MEAN: 0:0857 (158.82 M)
LONG. 77° 9:9259 +/- 0:5409 (909.35 M) 0:0097 (178.95 M)
ANT. HEIGHT: 248.61 M +/- 1237.80 M DEV. OF MEAN: 222.32 M



DAY 54-58 1972 KK CALLAO HT: +28 M # 17

4/5

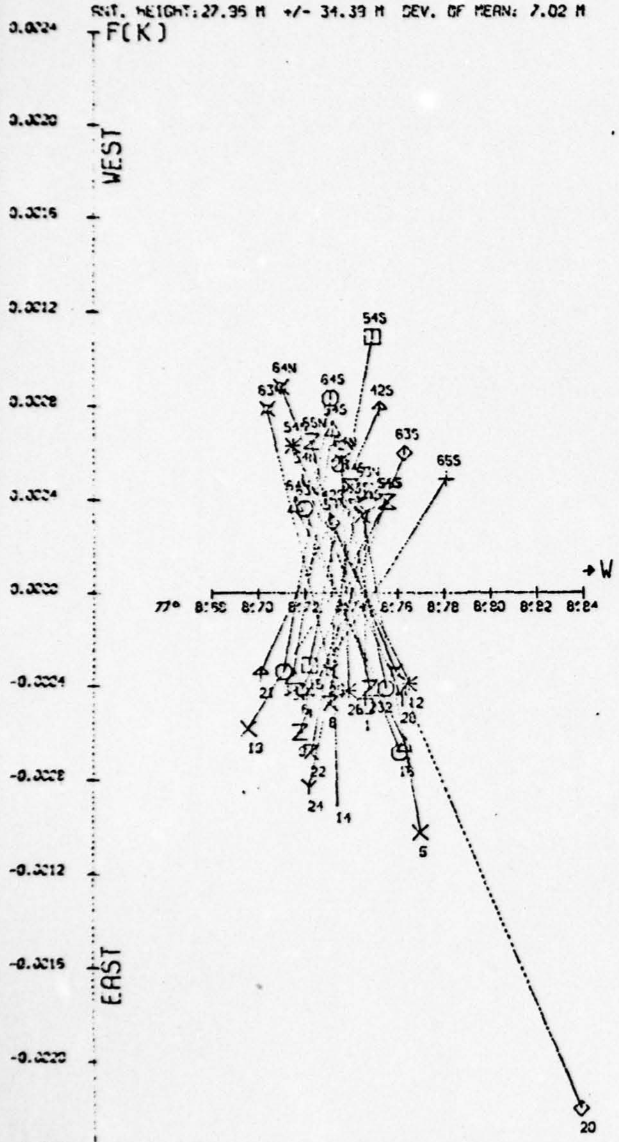
LAT.: -12° 2:8513 +/- 0:0832 (154.22 M) DEV. OF MEAN: 0:0111 (20.61 M)
LONG.. 77° 8:7362 +/- 0:0144 (26.10 M) 0:0027 (4.93 M)
ANT. HEIGHT: 30.58 M +/- 35.20 M DEV. OF MEAN: 6.65 M



DAY 54-58 1972 KK CALLAO HT: +28 M # 17 36

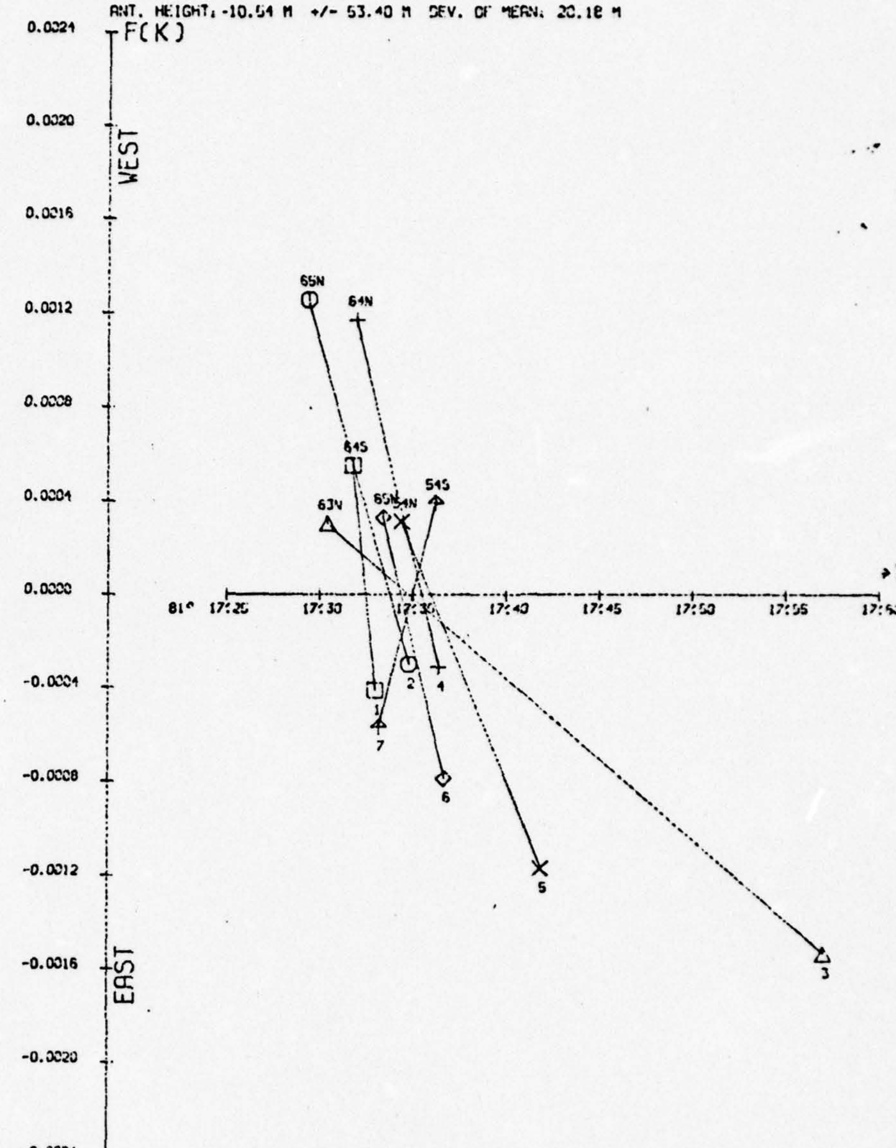
89 40

LAT.. -12° 2:8398 +/- 0:0273 (50.53 M) DEV. OF MEAN: 0:0039 (7.29 M)
LONG. 77° 8:7363 +/- 0:0098 (17.74 M) 0:0020 (3.62 M)
ANT. HEIGHT: 27.36 M +/- 34.39 M DEV. OF MEAN: 7.02 M



DAY 54-58 1972 KK CALLAO HT: +28 M # 17 26

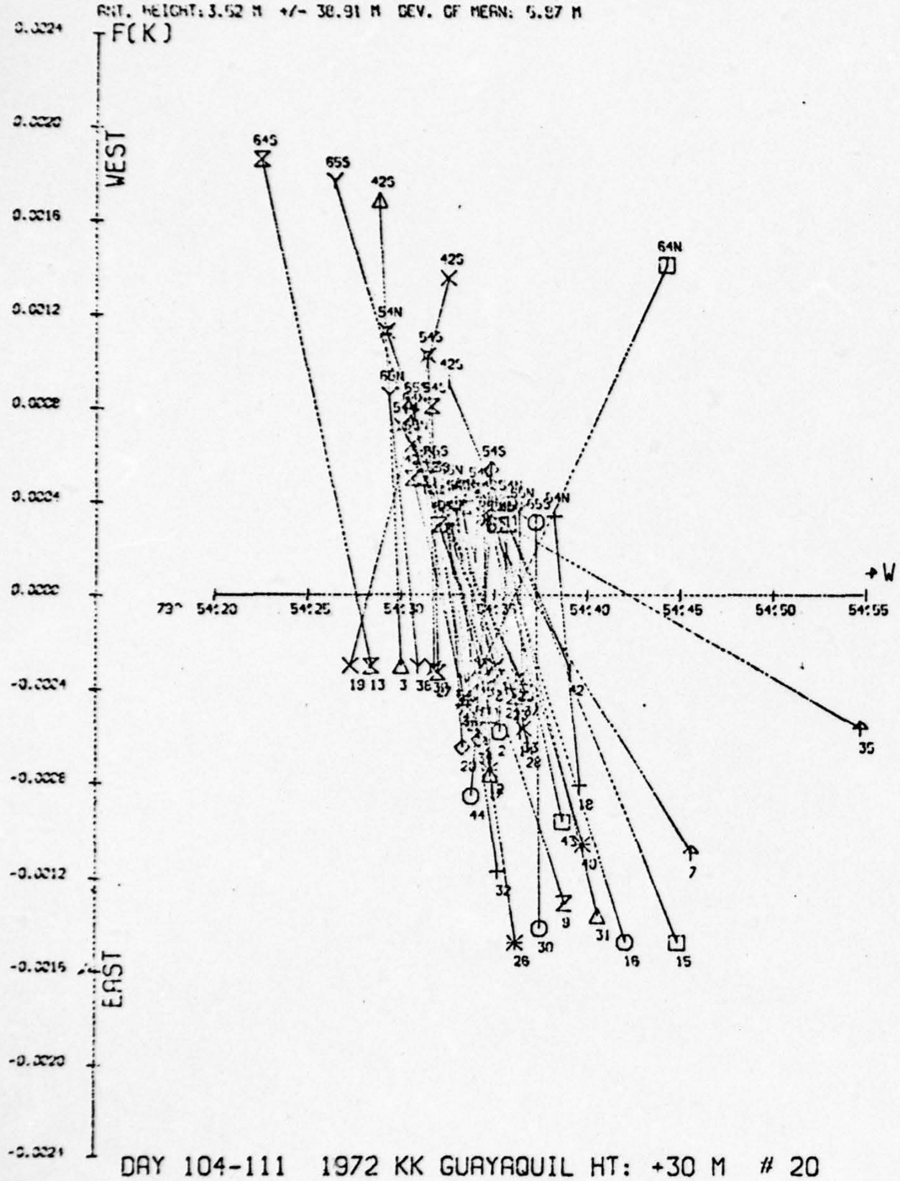
LAT.: -4° 33:7412 +/- 0:0890 (164.96 M) DEV. OF MEAN: 0:0238 (44.03 M)
LONG.. 81° 17:3455 +/- 0:0116 (21.43 M) 0:0044 (8.10 M)
ANT. HEIGHT: -10.54 M +/- 53.40 M DEV. OF MEAN: 20.18 M

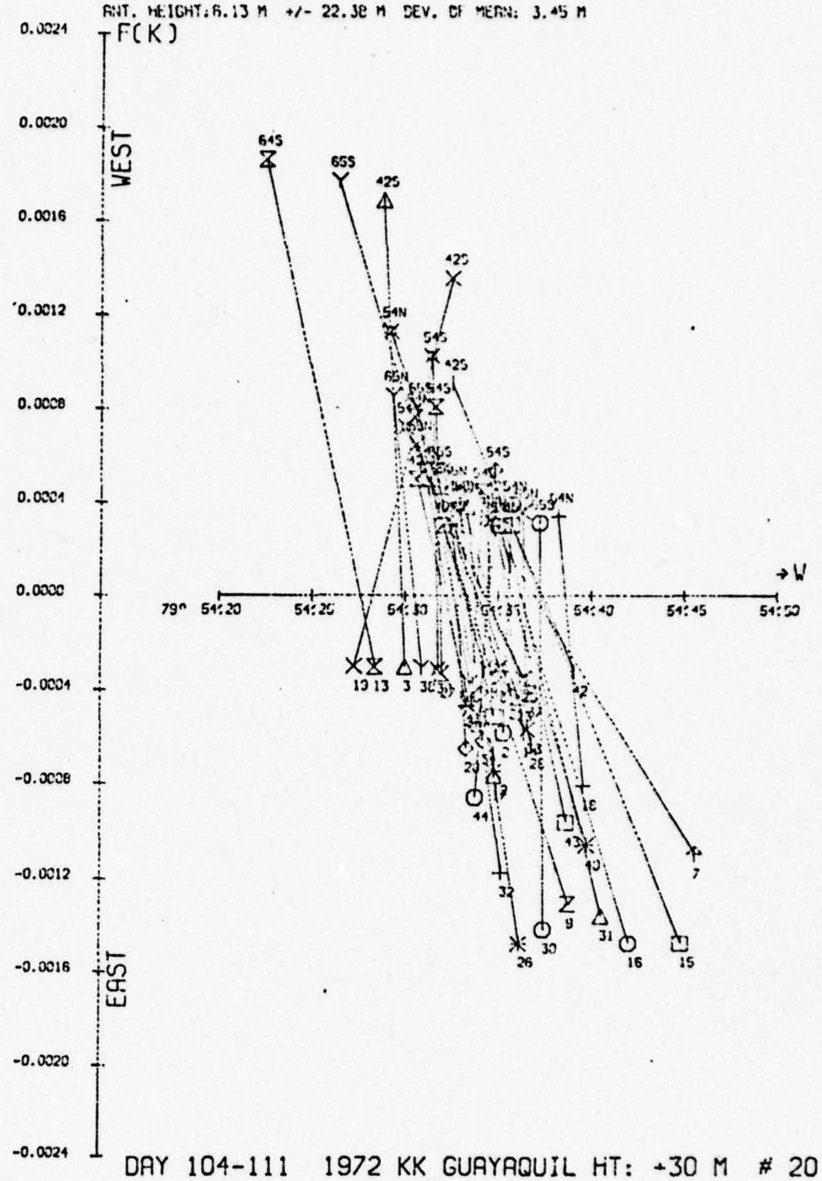


DAY 74-75 1972 KK TALARA HT: +28 M # 19 SWINGING (30

(25)

47 48

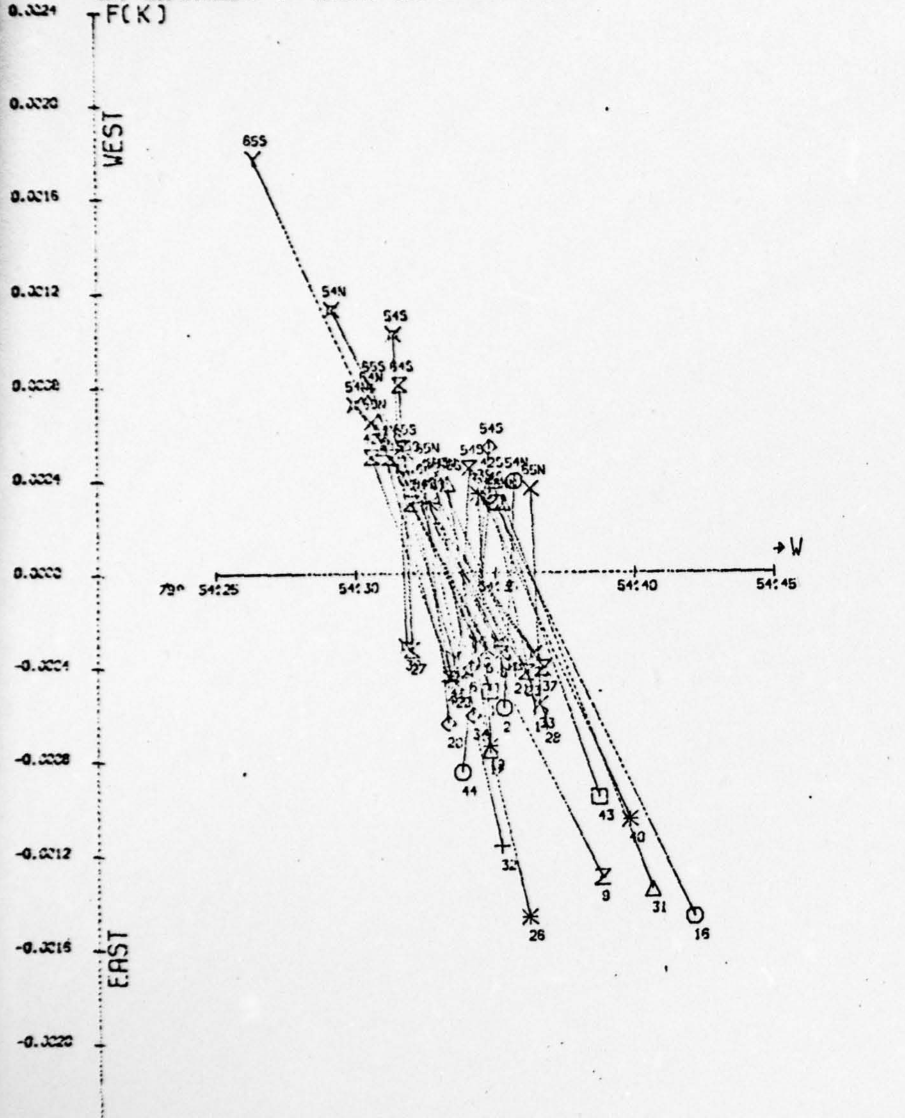




COMPLOT.

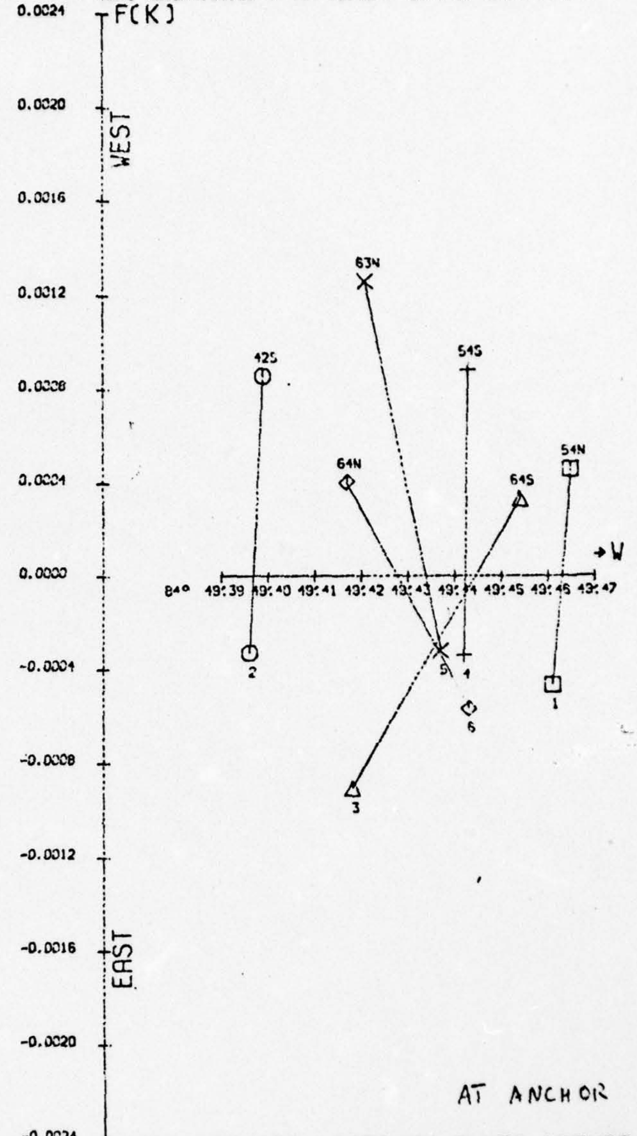
12

LAT.: -2° 15:9346 +/- 0:0465 (86.15 M) DEV. OF MEAN: 0:0057 (10.60 M)
LONG.: 79° 54:3393 +/- 0:0131 (24.19 M) 0:0023 (4.21 M)
ANT. HEIGHT: 8.10 M +/- 19.16 M DEV. OF MEAN: 3.33 M



DAY 104-111 1972 KK GUAYAQUIL HT: +30 M # 20 20

LAT.: 9° 57:8572 +/- 0:0274 (50.84 M) DEV. OF MEAN: 0:0072 (14.68 M)
LONG.: 84° 49:4346 +/- 0:0221 (40.32 M) 0:0090 (16.46 M)
ANT. HEIGHT: 14.96 M +/- 18.12 M DEV. OF MEAN: 7.40 M

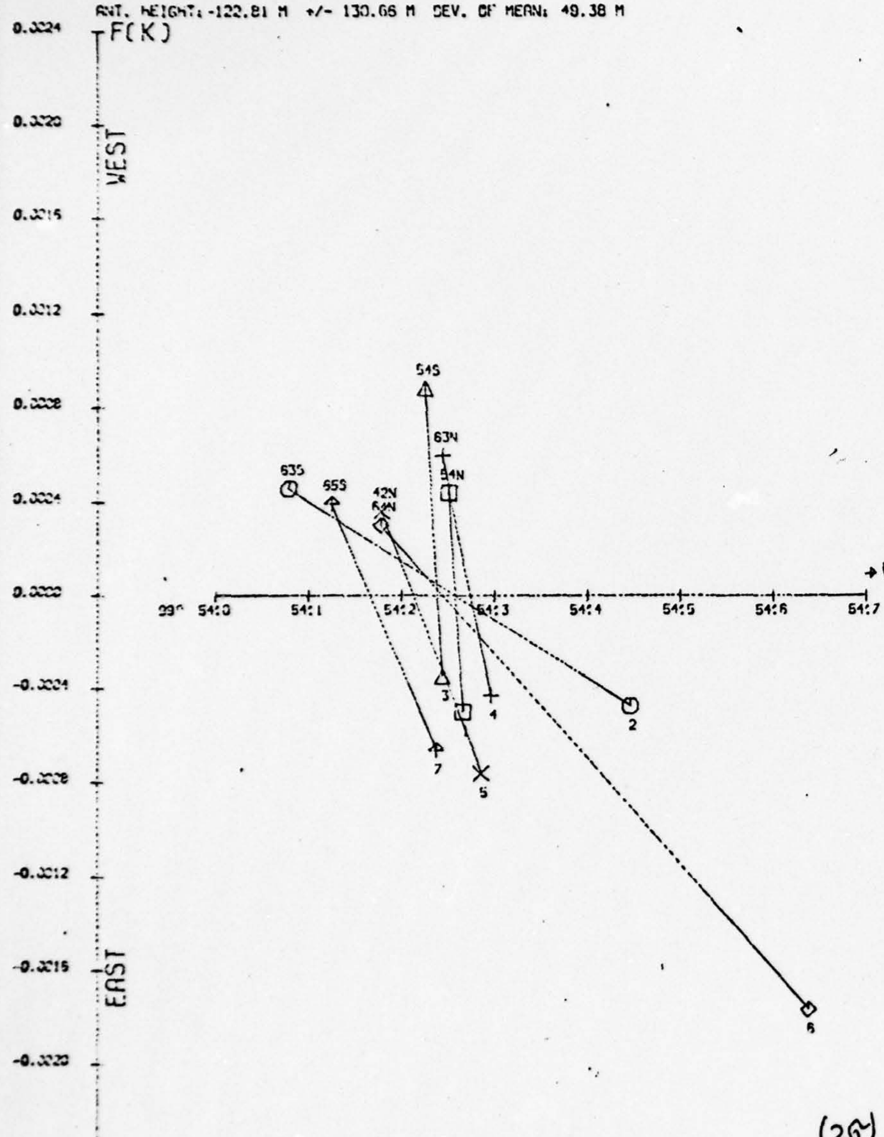


AT ANCHOR

DAY 122-123 1972 KK PUNTA ARENAS HT: +15 M # 21 (30) (20)

50.

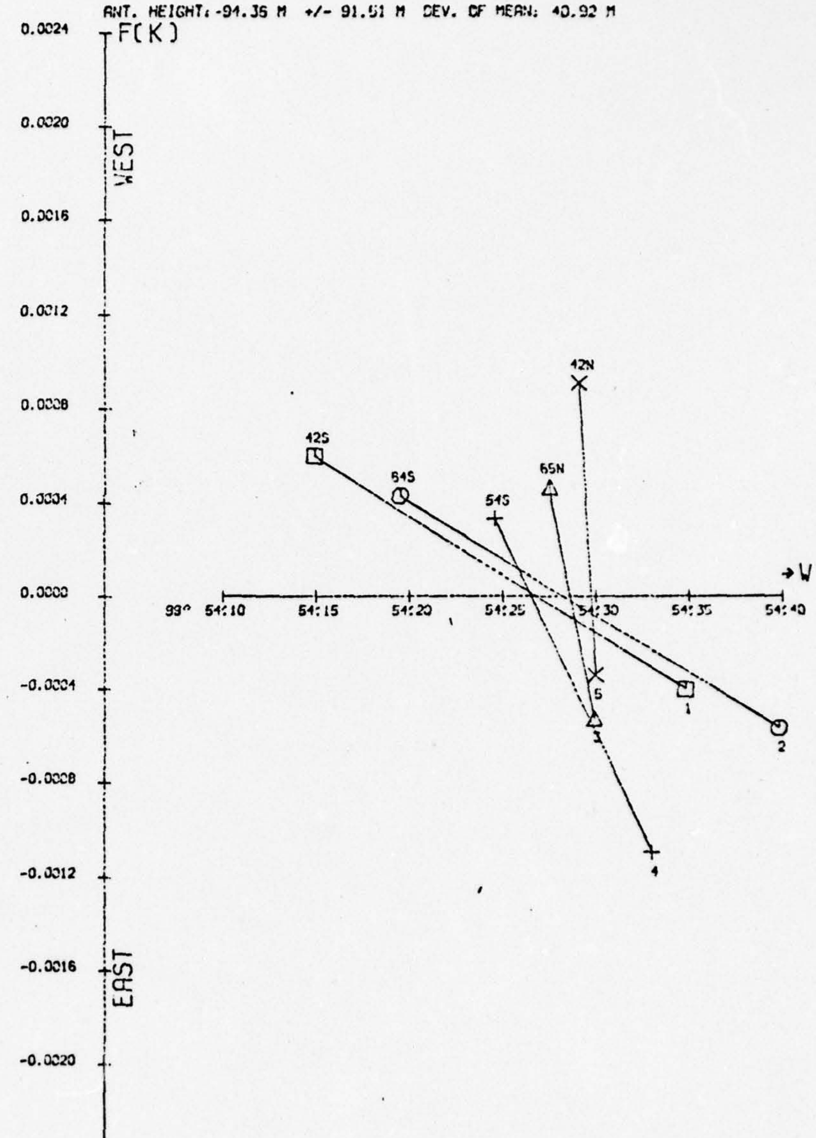
LAT.: 16° 50:3131 +/- 0:0635 (117.92 M) DEV. OF MEAN: 0:0170 (31.52 M)
LONG.. 93° 54:2363 +/- 0:0352 (64.29 M) 0:0137 (24.30 M)
ANT. HEIGHT: -122.81 M +/- 130.66 M DEV. OF MEAN: 49.38 M



DAY 132-133 1972 KK ACAPULCO HT: 0 M # 22 (2σ) (3σ)

51.

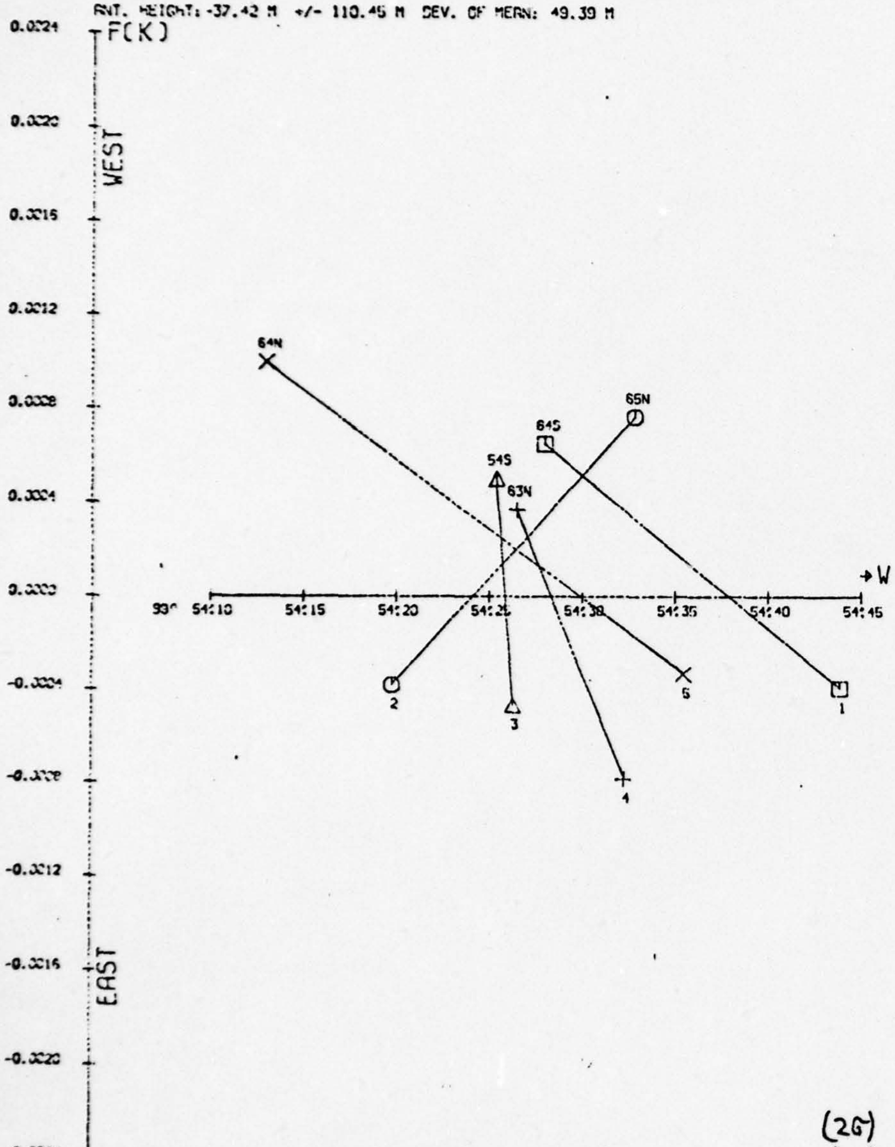
LAT.: 16° 50:9266 +/- 0:0666 (123.46 M) DEV. OF MEAN: 0:0211 (39.04 M)
LONG.. 93° 54:2700 +/- 0:0133 (23.59 M) 0:0053 (10.55 M)
ANT. HEIGHT: -94.36 M +/- 91.51 M DEV. OF MEAN: 40.92 M



DAY 133-134 1972 KK ACAPULCO HT: 0 M # 23A (2σ) (3σ)

52

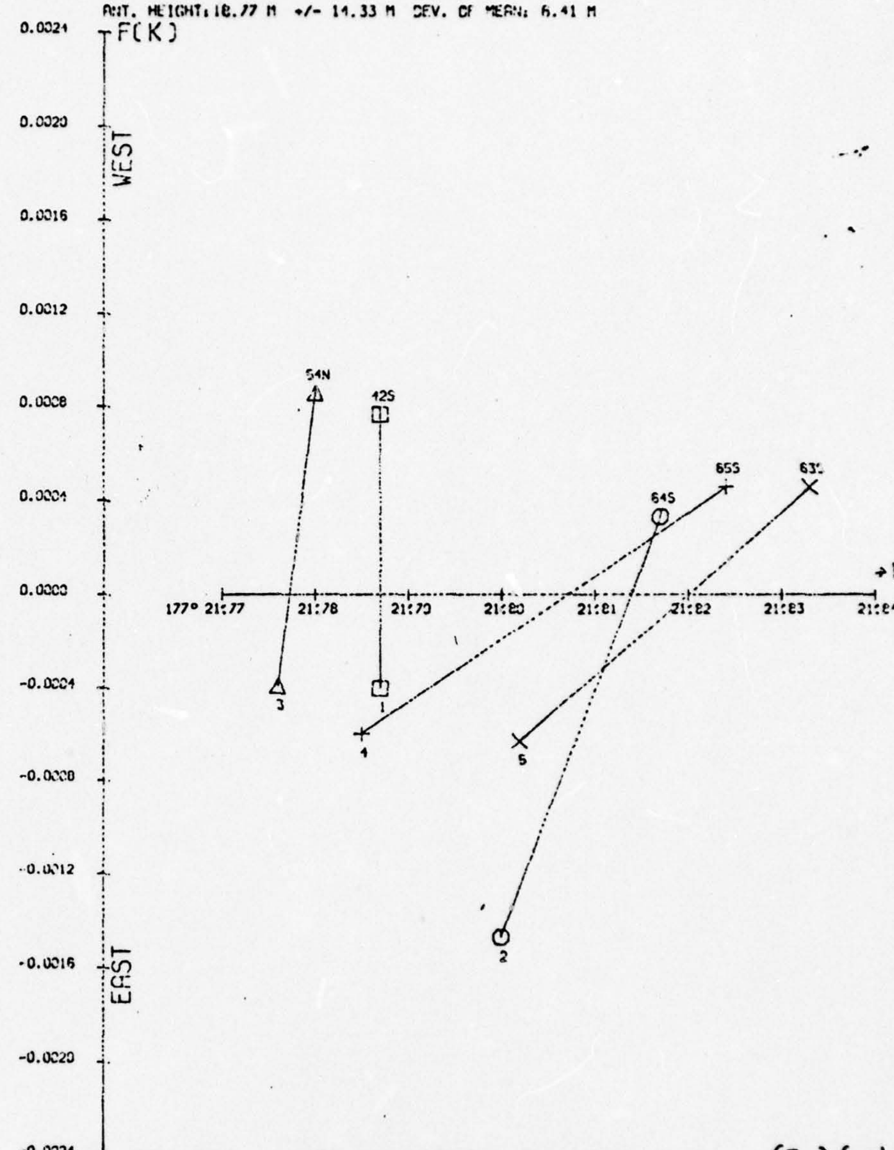
LAT.: 16° 50:8348 +/- 0:0366 (71.53 M) DEV. OF MEAN: 0:0122 (22.62 M)
LONG.. 99° 54:2322 +/- 0:0533 (94.62 M) 0:0239 (42.32 M)
ANT. HEIGHT: -37.42 M +/- 110.45 M DEV. OF MEAN: 49.39 M



DAY 136-138 1972 KK ACAPULCO HT: +14 M #23B (2σ) (3σ)

54

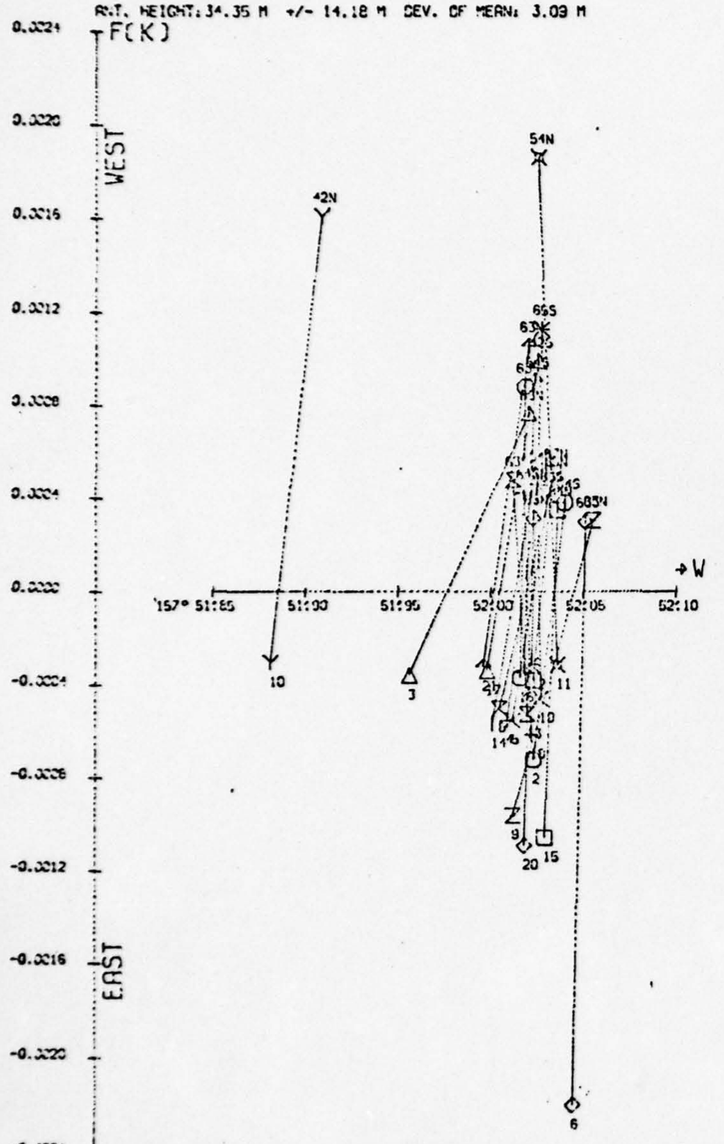
LAT.: 28° 12:8518 +/- 0:0239 (44.21 M) DEV. OF MEAN: 0:0075 (13.98 M)
LONG.. 177° 21:8010 +/- 0:0182 (29.69 M) 0:0081 (13.28 M)
ANT. HEIGHT: 18.77 M +/- 14.33 M DEV. OF MEAN: 6.41 M



DAY 203 1972 KK MIDWAY HT: +5 M # 24 (3σ)(2σ)

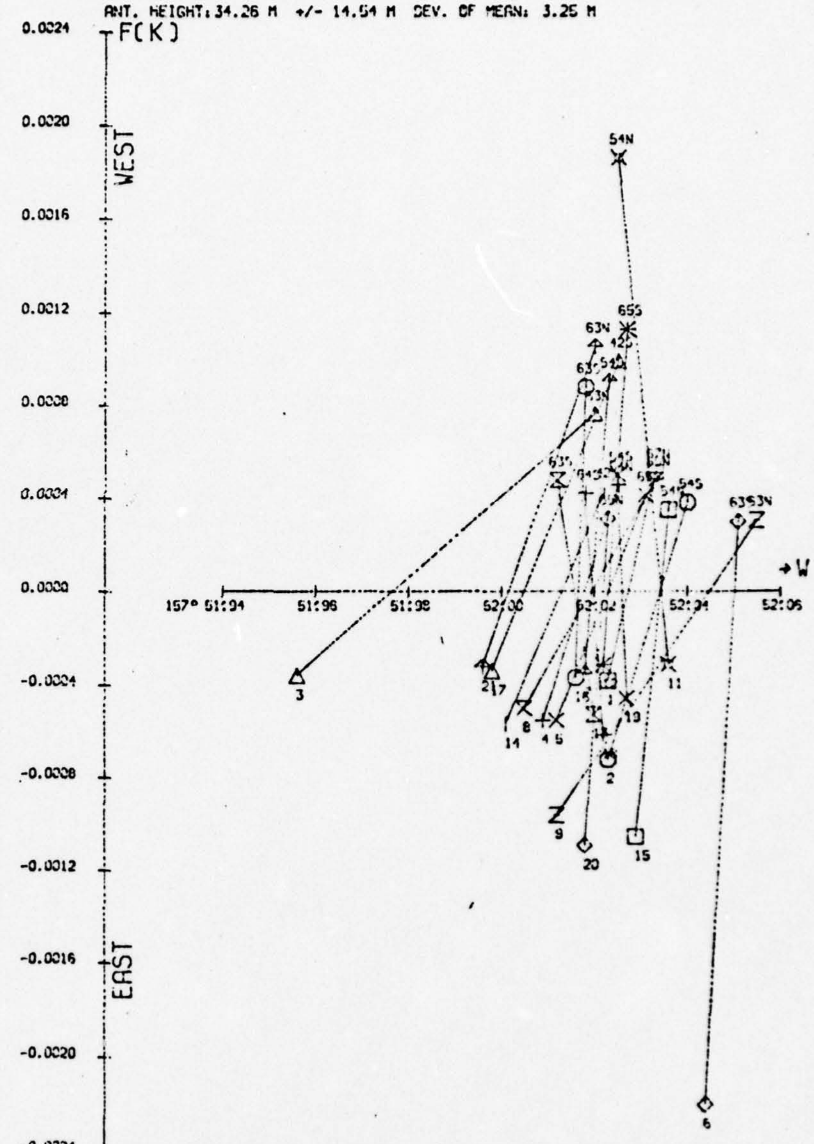
55 56

LAT.: 21° 18:8042 +/- 0:0386 (71.46 M) DEV. OF MEAN: 0:0060 (11.03 M)
LONG.. 157° 52:0146 +/- 0:0334 (57.70 M) 0:0073 (12.59 M)
ANT. HEIGHT: 34.35 M +/- 14.18 M DEV. OF MEAN: 3.09 M



DAY 306-313 1972 KK HNL HT: +23 M # 25

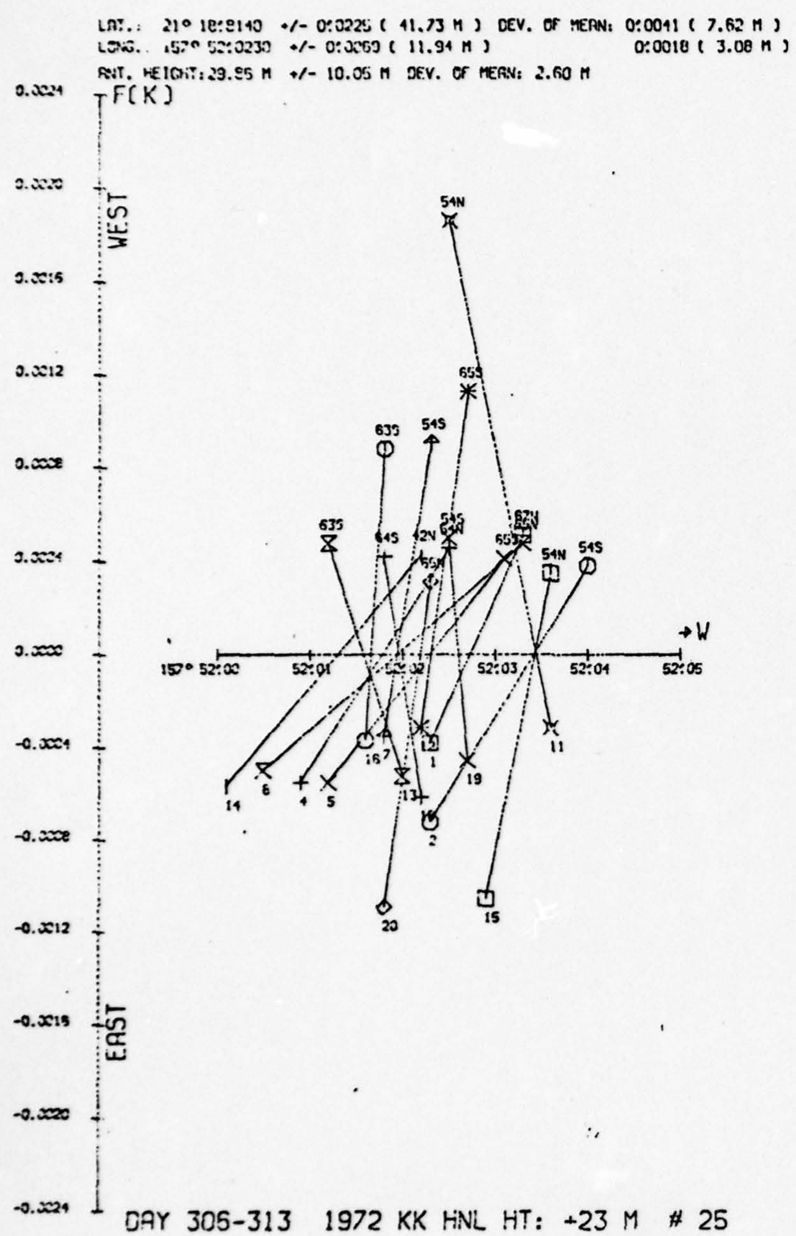
LAT.: 21° 18:8093 +/- 0:0229 (42.42 M) DEV. OF MEAN: 0:0036 (6.71 M)
LONG.. 157° 52:0211 +/- 0:0158 (27.31 M) 0:0035 (6.11 M)
ANT. HEIGHT: 34.26 M +/- 14.54 M DEV. OF MEAN: 3.25 M



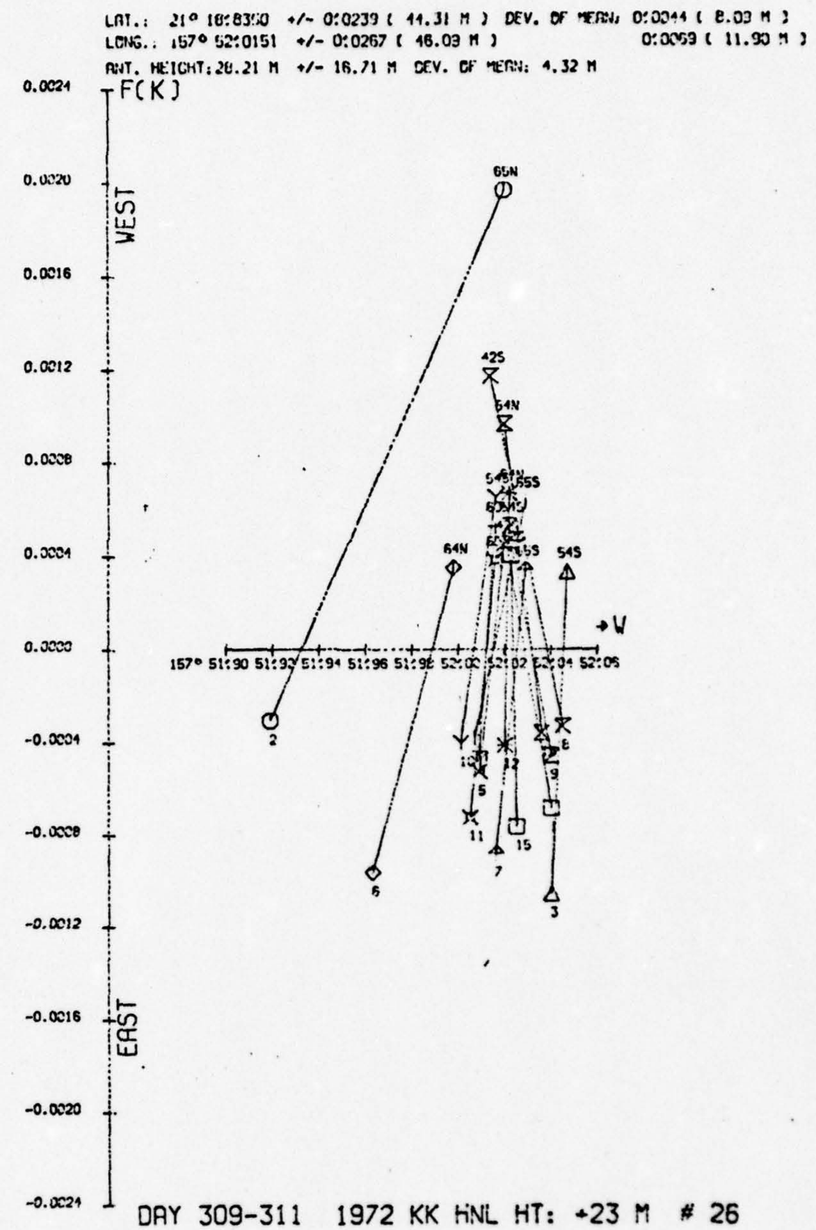
DAY 306-313 1972 KK HNL HT: +23 M # 25 3σ

98

5

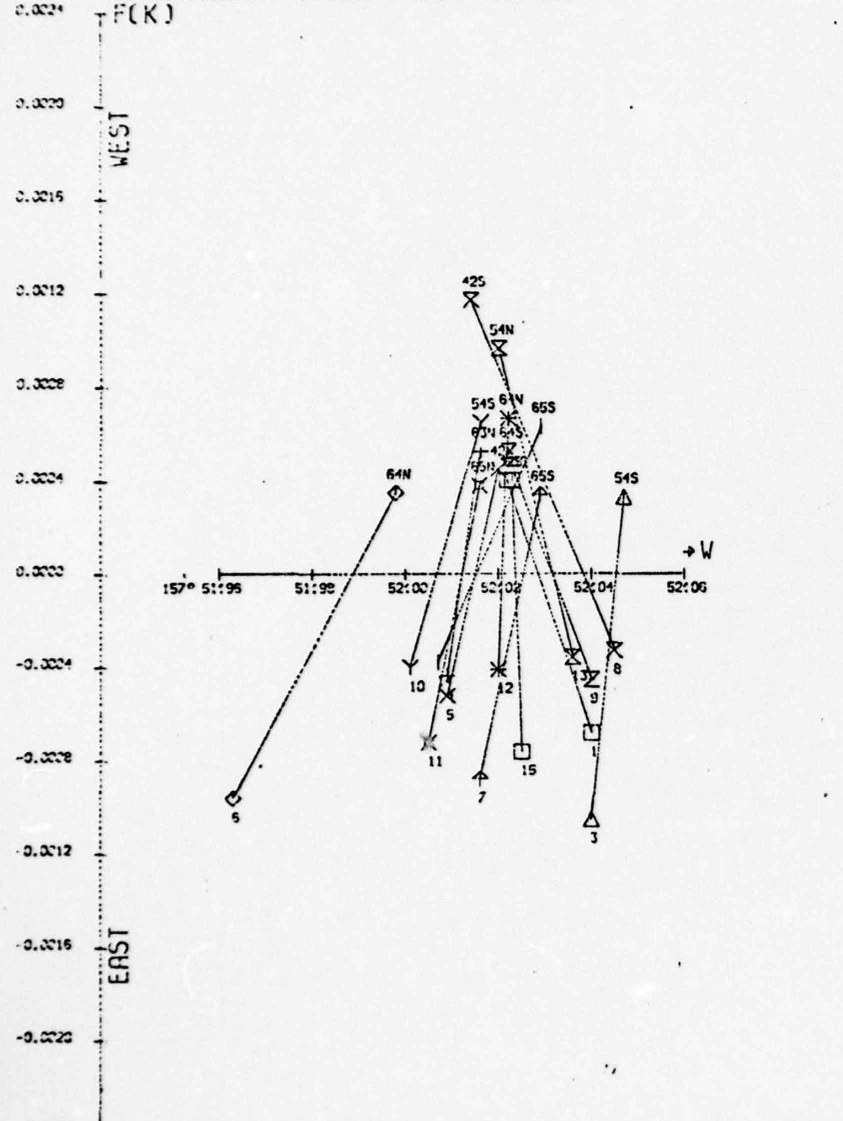

LAT.: 21° 18:8140 +/- 0:0225 (41.73 M) DEV. OF MEAN: 0:0041 (7.62 M)
LONG.: 157° 52:0230 +/- 0:0069 (11.94 M) 0:0018 (3.08 M)
ANT. HEIGHT: 29.95 M +/- 10.05 M DEV. OF MEAN: 2.60 M
F(K)
WEST
EAST
→W
DAY 306-313 1972 KK HNL HT: +23 M # 25

2σ


LAT.: 21° 18:8350 +/- 0:0239 (44.31 M) DEV. OF MEAN: 0:0044 (8.03 M)
LONG.: 157° 52:0151 +/- 0:0267 (46.09 M) 0:0069 (11.90 M)
ANT. HEIGHT: 28.21 M +/- 16.71 M DEV. OF MEAN: 4.32 M
F(K)
WEST
EAST
→W
DAY 309-311 1972 KK HNL HT: +23 M # 26

58

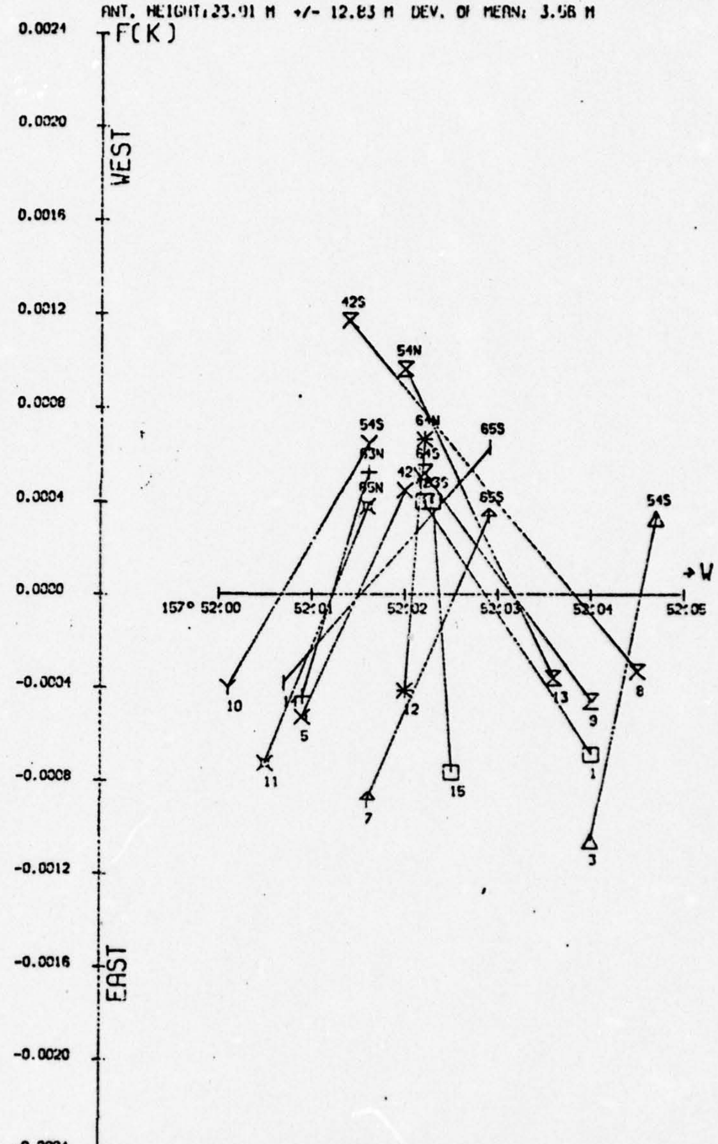
LAT.. 21° 18:8326 +/- 0:0222 (41.15 M) DEV. OF MEAN: 0:0042 (7.78 M)
LONG. 157° 52:0211 +/- 0:0143 (24.74 M) 0:0038 (6.61 M)
ANT. HEIGHT:25.62 M +/- 13.88 M DEV. OF MEAN: 3.71 M



DAY 309-311 1972 KK HNL HT: +23 M # 26 3σ

100

LAT.: 21° 18:8369 +/- 0:0223 (41.29 M) DEV. OF MEAN: 0:0044 (8.10 M)
LONG.. 157° 52:0235 +/- 0:0113 (19.56 M) 0:0031 (5.42 M)
ANT. HEIGHT:23.91 M +/- 12.83 M DEV. OF MEAN: 3.58 M

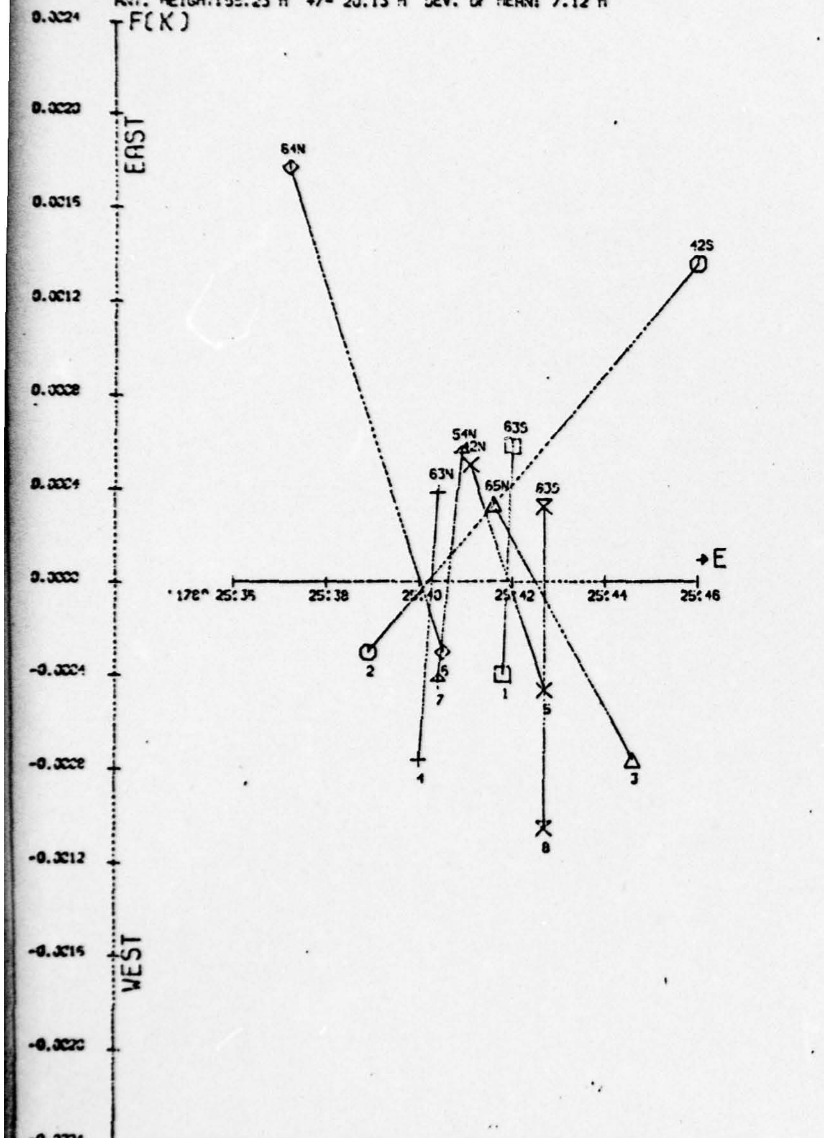


DAY 309-311 1972 KK HNL HT: +23 M # 26 2σ

59

102

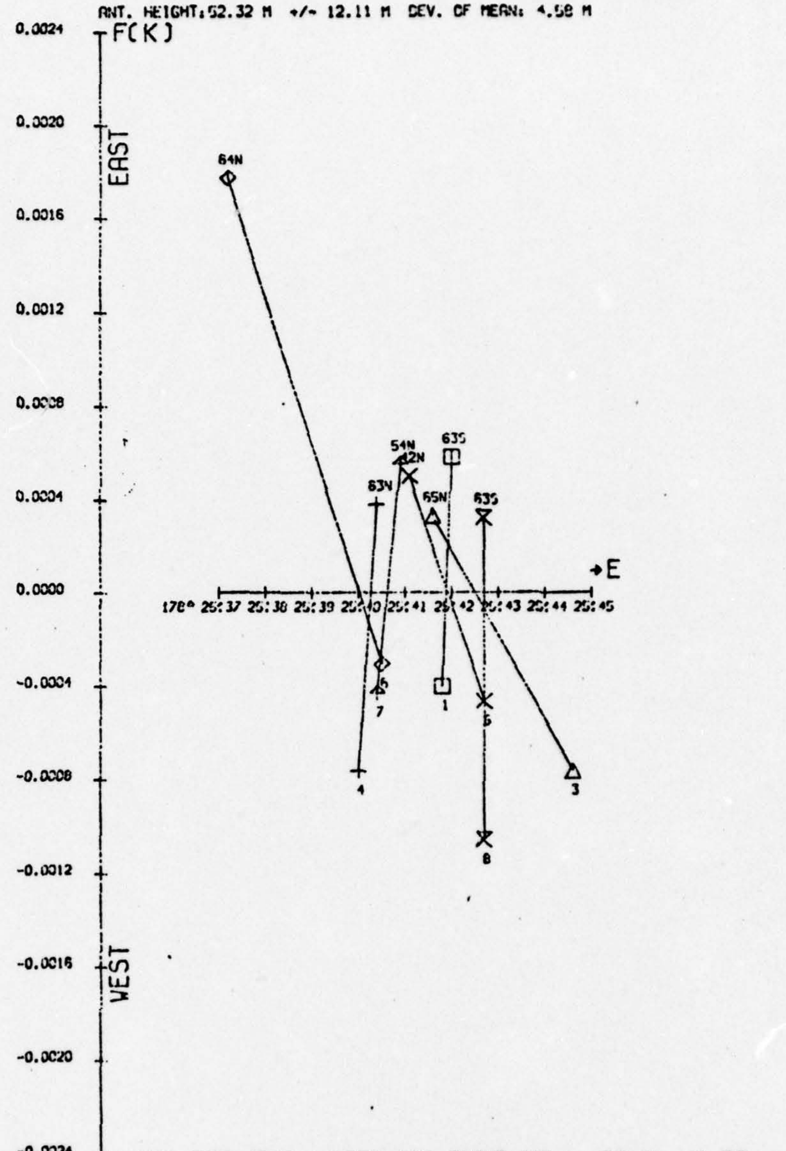
LAT.: -18° 7:3952 +/- 0:0302 (56.03 M) DEV. OF MEAN: 0:0076 (14.01 M)
LONG.. 178° 25:4126 +/- 0:0110 (13.44 M) 0:0039 (6.87 M)
ANT. HEIGHT:58.23 M +/- 20.13 M DEV. OF MEAN: 7.12 M



DAY 359-360 1972 KK SUVA HT: +59 M # 28 (3σ)

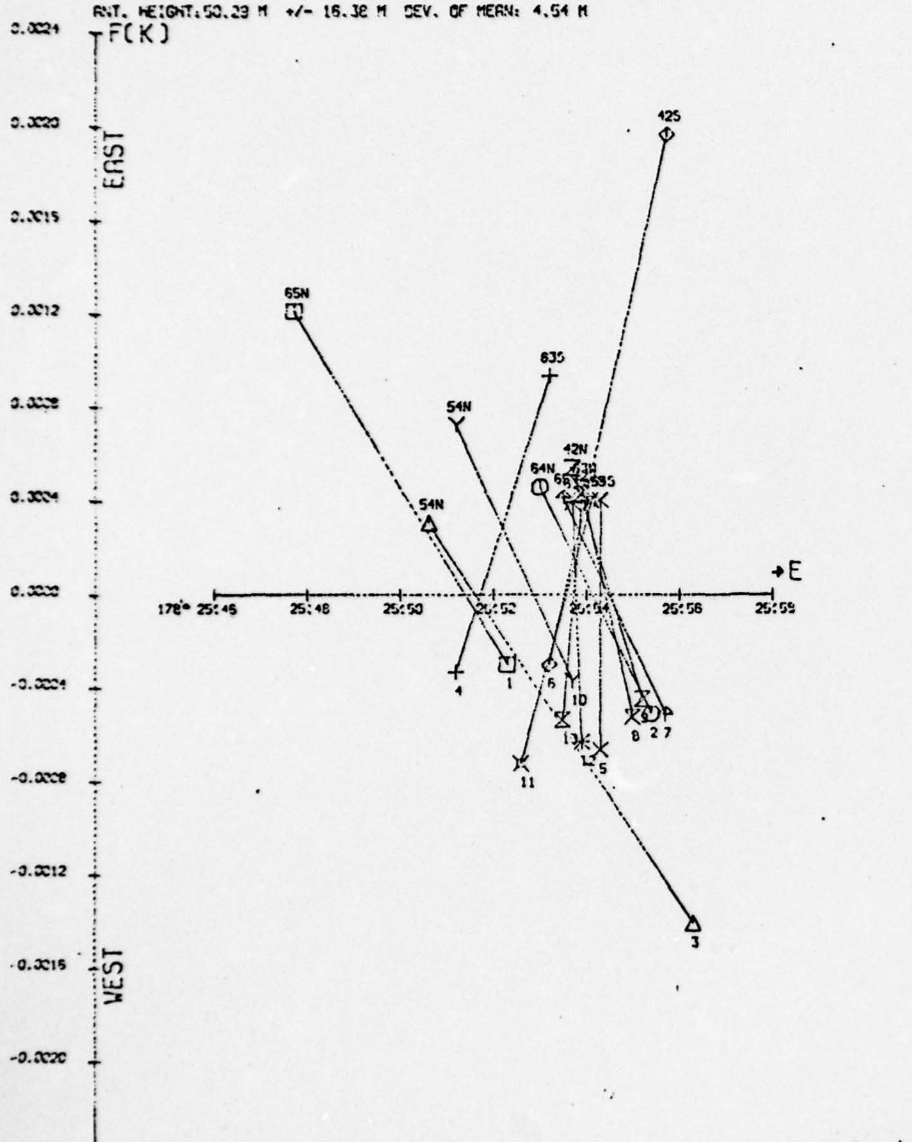
COMPLOT

LAT.: -18° 8:0022 +/- 0:0210 (39.00 M) DEV. OF MEAN: 0:0056 (10.42 M)
LONG.. 178° 25:4141 +/- 0:0110 (19.35 M) 0:0042 (7.31 M)
ANT. HEIGHT:52.32 M +/- 12.11 M DEV. OF MEAN: 4.58 M



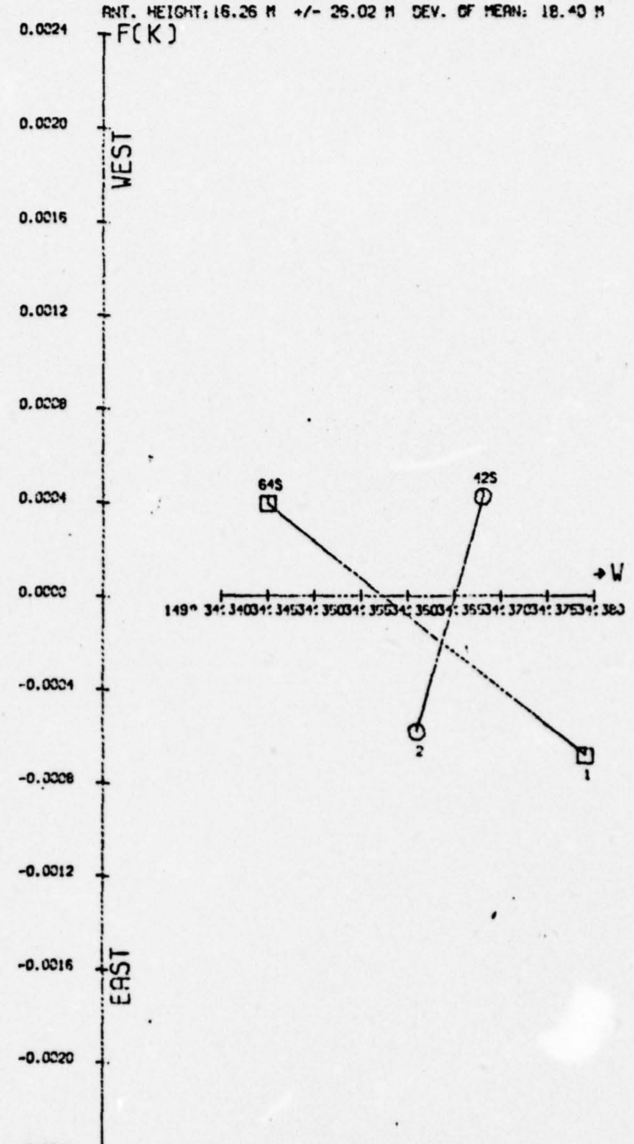
DAY 359-360 1972 KK SUVA HT: +59 M # 28 2σ

LAT.: -18° 7:7800 +/- 0:0198 (36.65 M) DEV. OF MEAN: 0:0039 (7.19 M)
LONG. 178° 25:5338 +/- 0:0113 (19.97 M) 0:0031 (5.54 M)
ANT. HEIGHT: 50.29 M +/- 16.38 M DEV. OF MEAN: 4.54 M



DAY 360-362 1972 KK SUVA HT: +59 M # 29 (3σ) (2σ)

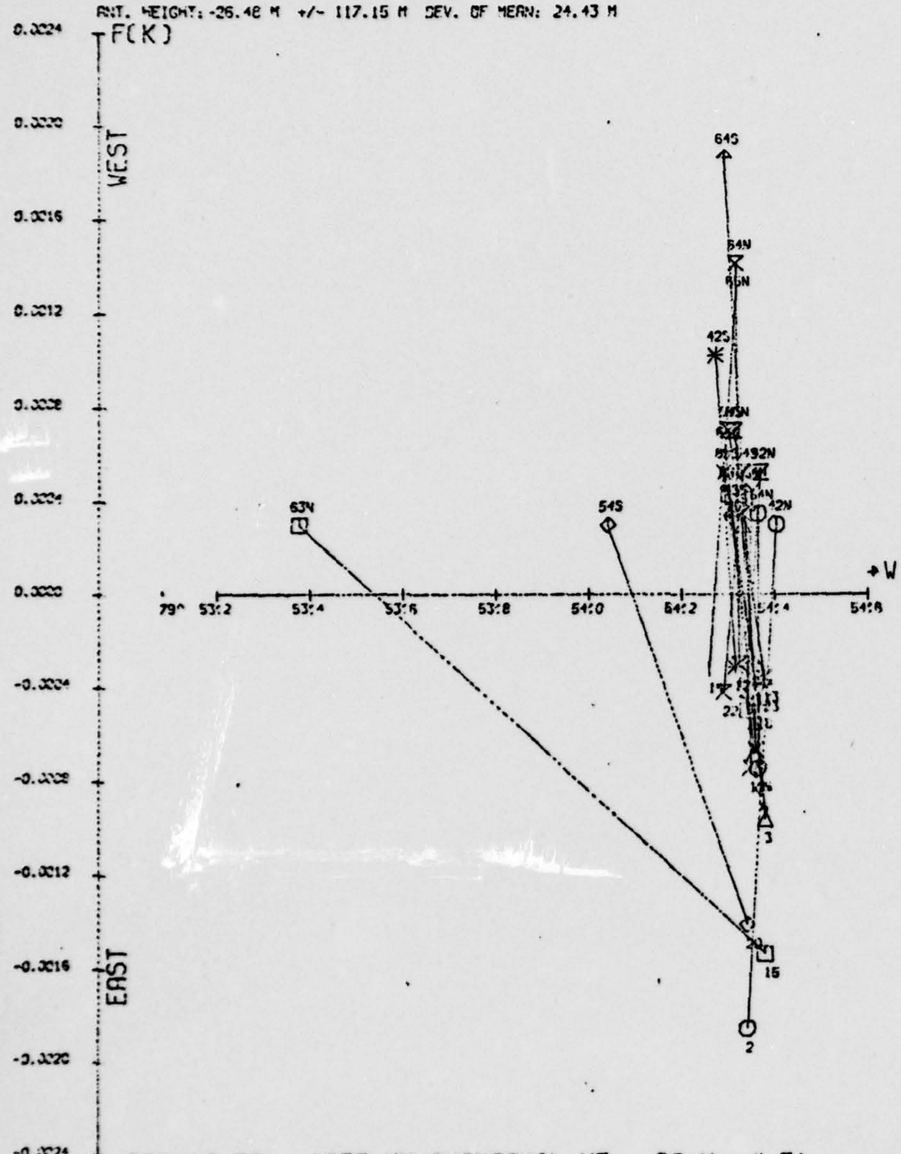
LAT.: -17° 32:0200 +/- 0:0320 (59.38 M) DEV. OF MEAN: 0:0160 (29.69 M)
LONG.: 149° 34:3612 +/- 0:0054 (9.59 M) 0:0038 (6.78 M)
ANT. HEIGHT: 16.26 M +/- 26.02 M DEV. OF MEAN: 18.40 M



DAY 21 1973 KK PAPEETE HT: +28 M # 30 (3σ) (2σ)

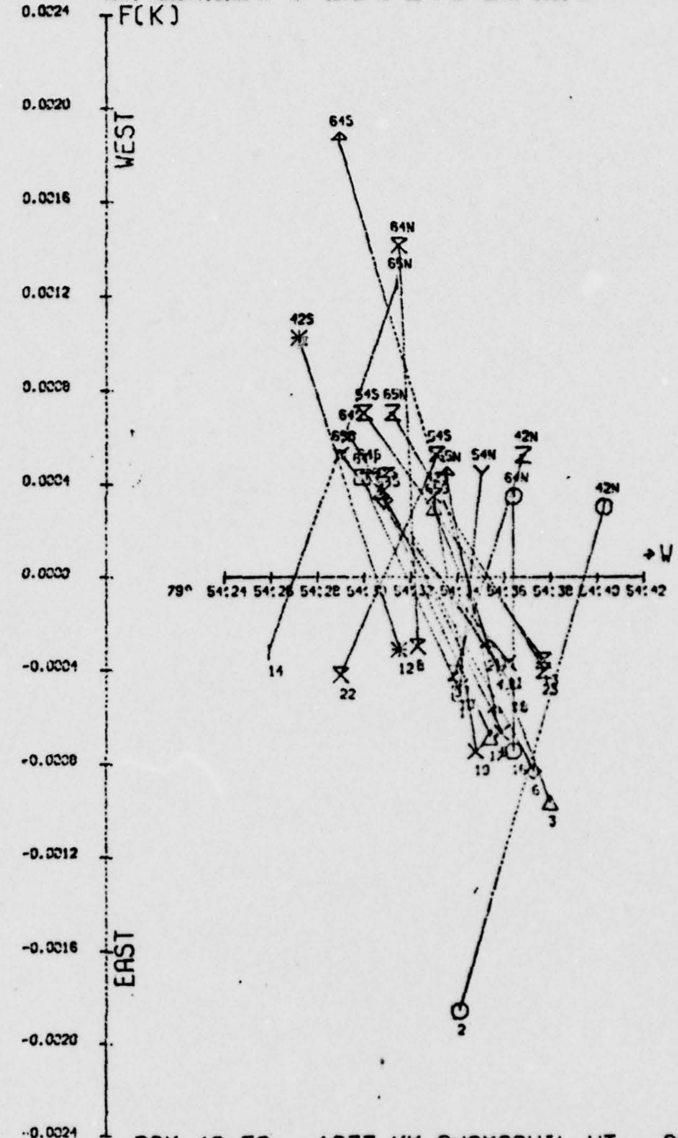
62

LAT.. -2° 17:0773 +/- 0:5055 (938.66 M) DEV. OF MEAN: 0:0747 (138.40 M)
LONG.. 79° 54:2824 +/- 0:1724 (319.16 M) 0:0359 (66.55 M)
ANT. HEIGHT: -26.48 M +/- 117.15 M DEV. OF MEAN: 24.43 M



DAY 46-50 1973 KK GUAYAQUIL HT: +28 M # 31

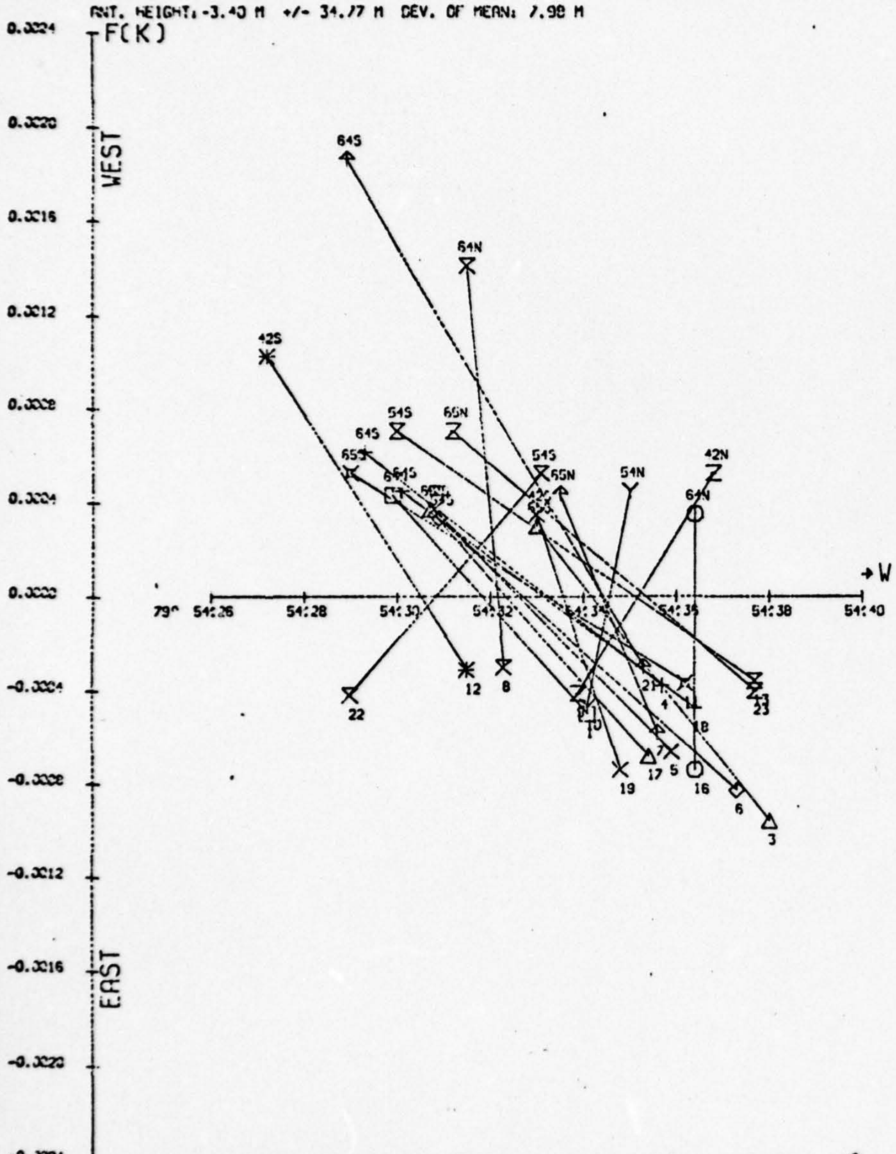
LAT.: -2° 17:0018 +/- 0:0511 (94.63 M) DEV. OF MEAN: 0:0079 (14.60 M)
LONG.. 79° 54:3343 +/- 0:0246 (45.58 M) 0:0054 (9.95 M)
ANT. HEIGHT: 2.61 M +/- 38.07 M DEV. OF MEAN: 8.31 M



DAY 46-50 1973 KK GUAYAQUIL HT: +28 M # 31 36

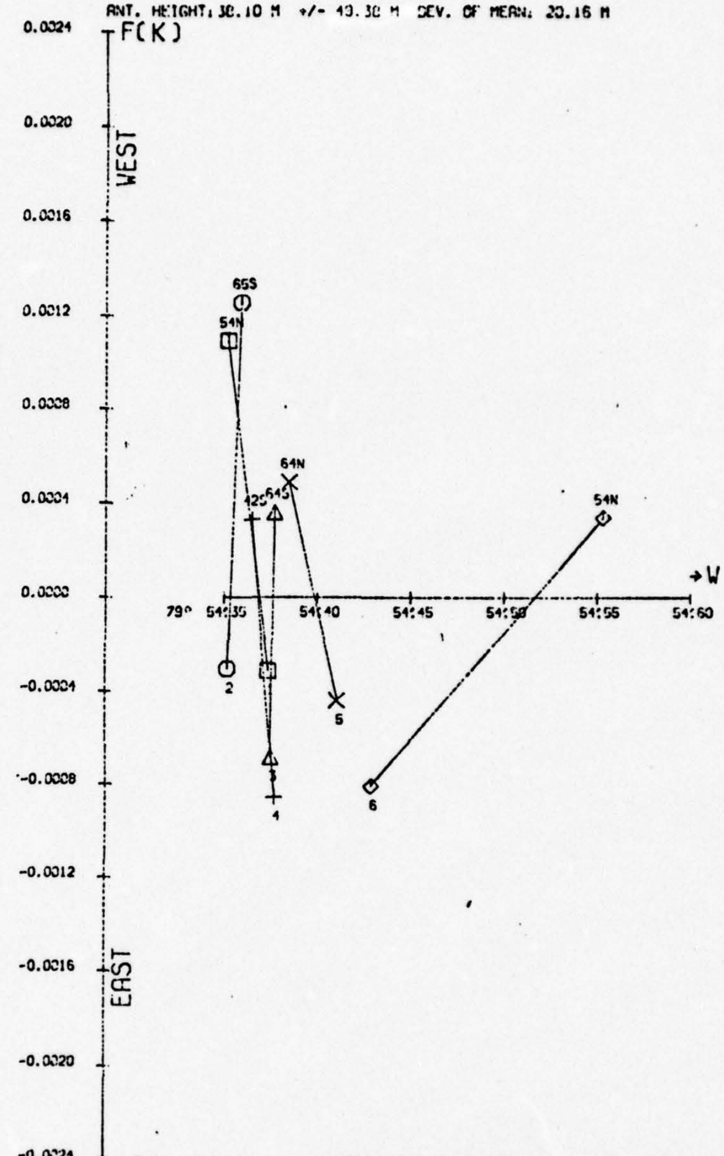
106 64

LAT.: -2° 16:9392 +/- 0:0530 (98.15 M) DEV. OF MEAN: 0:0086 (15.92 M)
LONG.. 79° 54:3346 +/- 0:0157 (28.99 M) 0:0036 (6.65 M)
ANT. HEIGHT: -3.40 M +/- 34.77 M DEV. OF MEAN: 7.98 M



DAY 46-50 1973 KK GUAYAQUIL HT: +28 M # 31 2σ

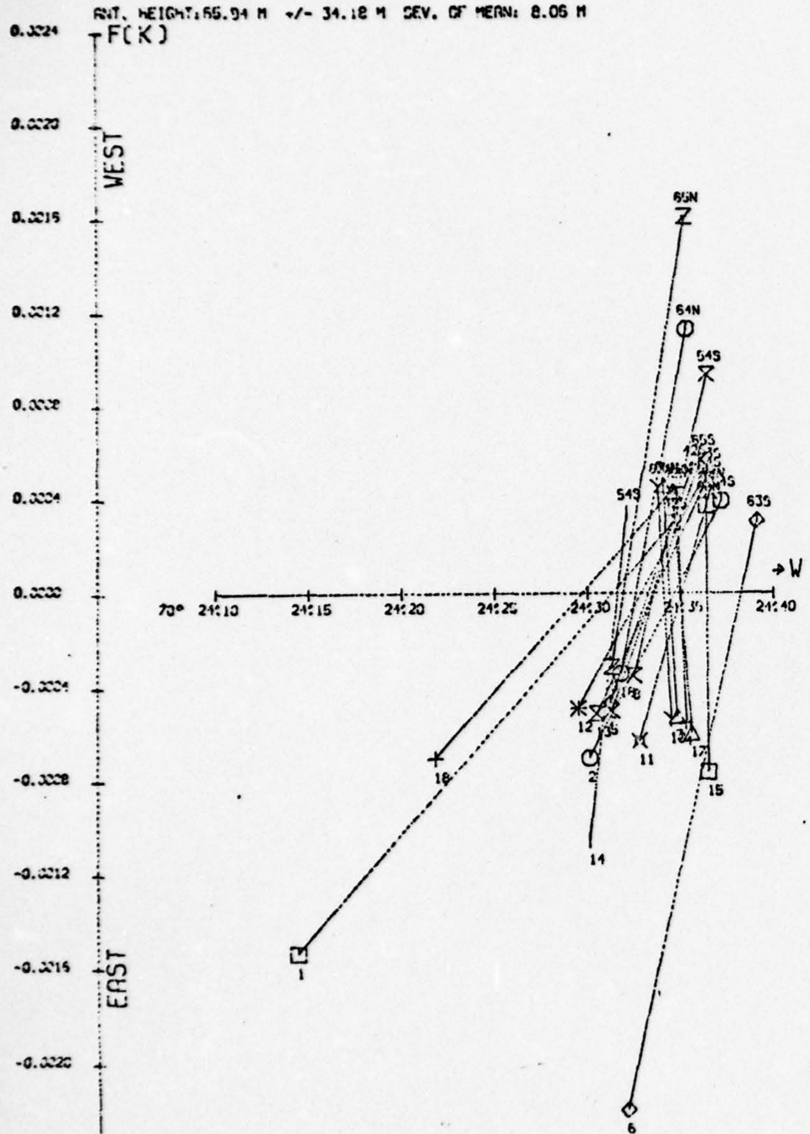
LAT.: -2° 16:9490 +/- 0:1108 (205.41 M) DEV. OF MEAN: 0:0320 (59.30 M)
LONG.. 79° 54:3970 +/- 0:0603 (111.60 M) 0:0246 (45.56 M)
ANT. HEIGHT: 30.10 M +/- 43.30 M DEV. OF MEAN: 20.16 M



DAY 50-51 1973 KK GUAYAQUIL HT: +28 M # 32 (2σ) (3σ)

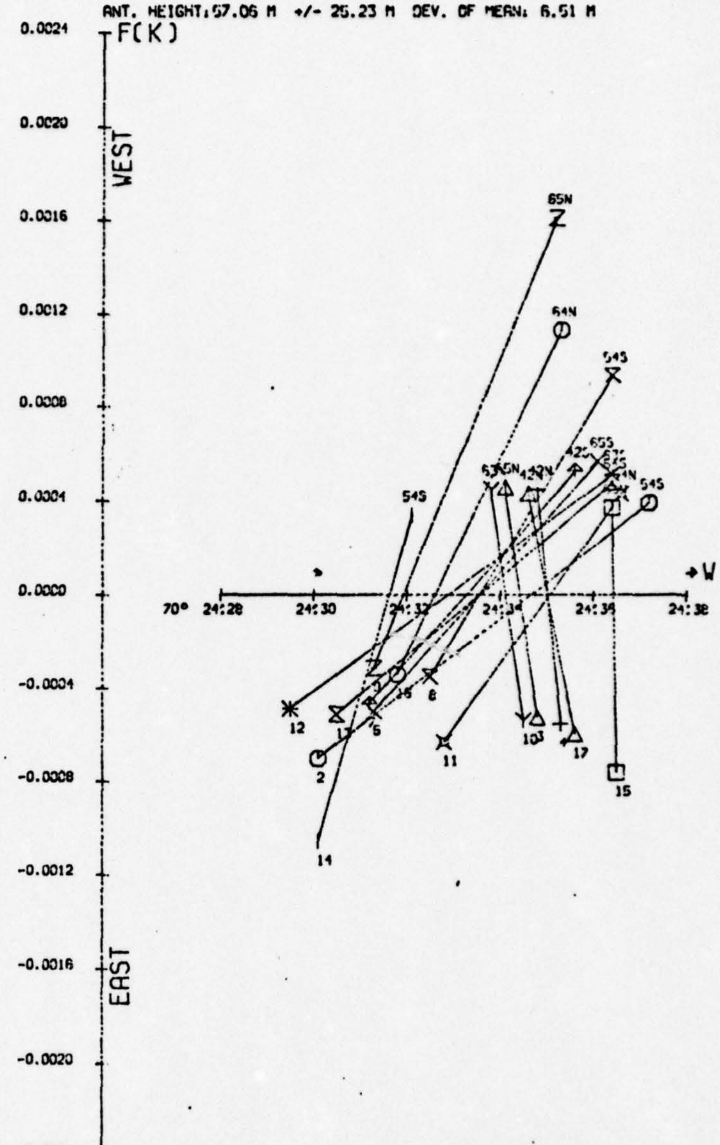
65 109

LAT.: -23° 39:2310 +/- 0:0597 (108.76 M) DEV. OF MEAN: 0:0038 (18.13 M)
LONG.. 70° 24:3372 +/- 0:0198 (33.61 M) 0:0047 (7.92 M)
ANT. HEIGHT:65.94 M +/- 34.18 M DEV. OF MEAN: 8.06 M



DAY 91-93 1973 KK ANTOFAGASTA HT: +34 M # 34 (3σ)

LAT.: -23° 39:2241 +/- 0:0244 (45.30 M) DEV. OF MEAN: 0:0045 (8.27 M)
LONG.. 70° 24:3384 +/- 0:0130 (22.08 M) 0:0034 (5.70 M)
ANT. HEIGHT:57.06 M +/- 25.23 M DEV. OF MEAN: 6.51 M

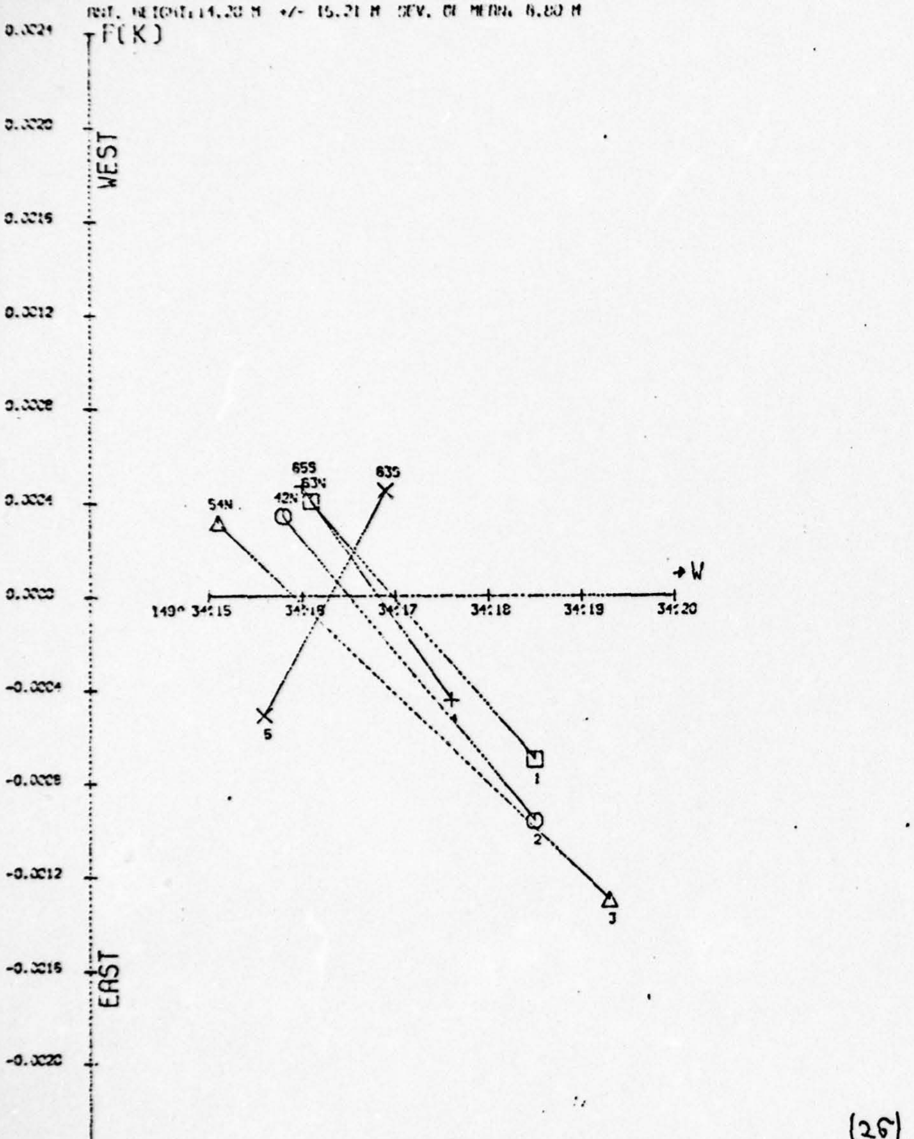


DAY 91-93 1973 KK ANTOFAGASTA HT: +34 M # 34 2σ

60

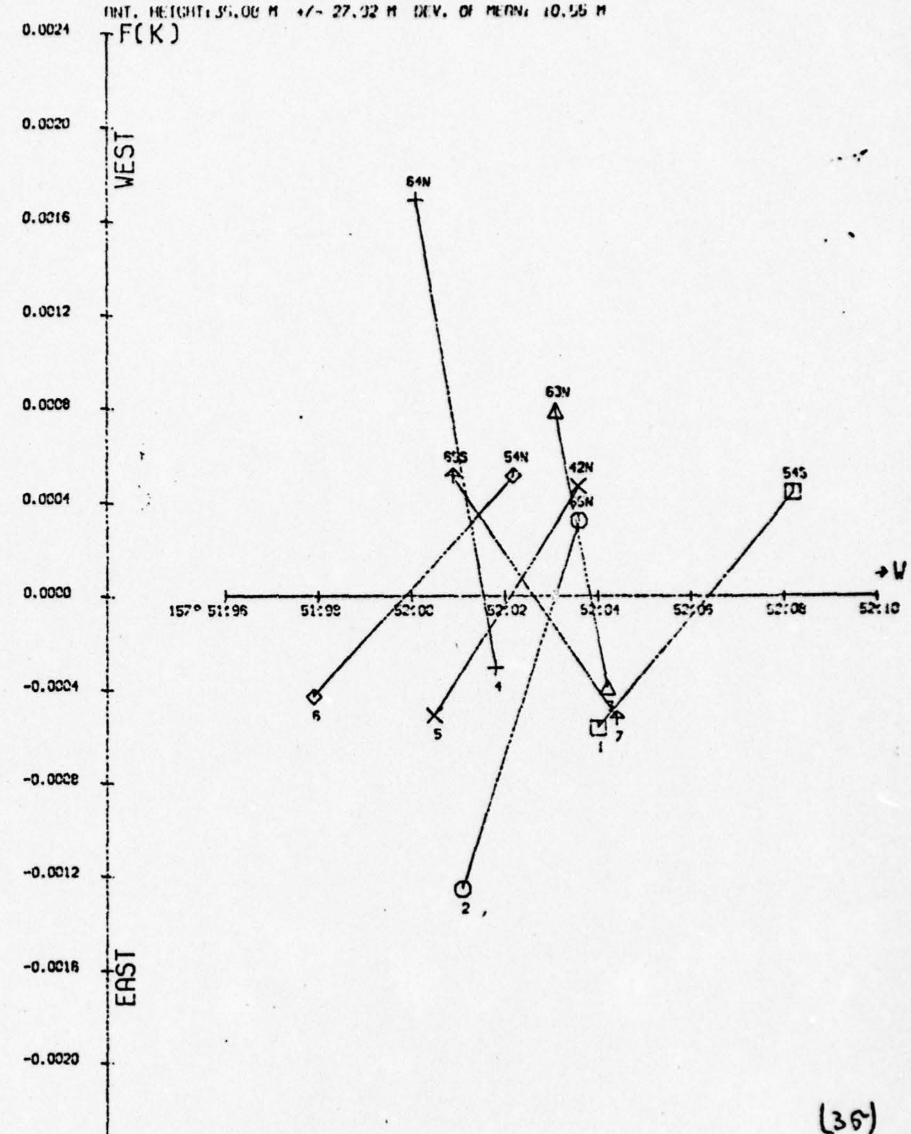
115

LAT.. -17° 32:2439 +/- 0:0192 (35.64 M) DEV. OF MEAN: 0:0061 (11.27 M)
LONG. 149° 34:1643 +/- 0:0242 (7.46 M) 0:0019 (3.34 M)
ANT. HEIGHT: 14.20 M +/- 15.21 M DEV. OF MEAN: 8.80 M



DAY 151-152 1973 KK PAPEETE HT: +28 M # 37 (2σ) (3σ)

LAT.: 21° 18:8108 +/- 0:0279 (51.79 M) DEV. OF MEAN: 0:0075 (13.84 M)
LONG.. 157° 52:0277 +/- 0:0202 (34.94 M) 0:0076 (13.21 M)
ANT. HEIGHT: 35.08 M +/- 27.32 M DEV. OF MEAN: 10.55 M

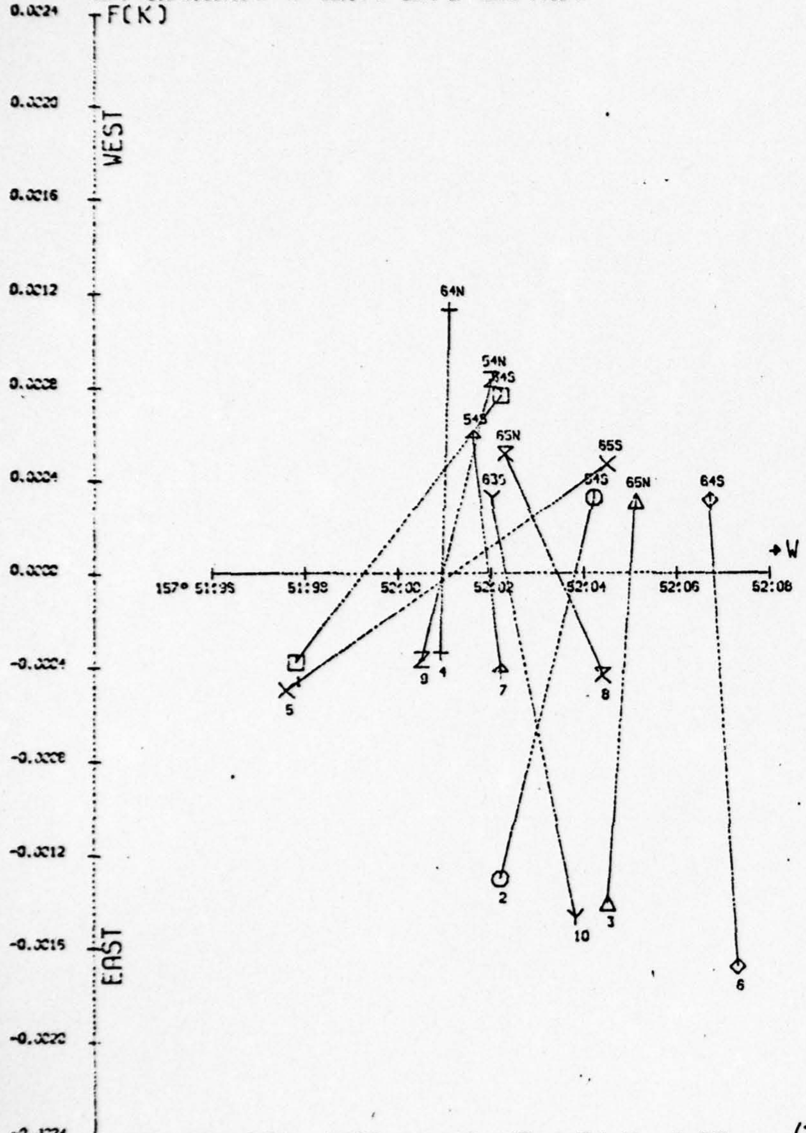


DAY 252-253 1973 KK HNL. HT: + 24 M # 39B (3σ) (2σ)

67

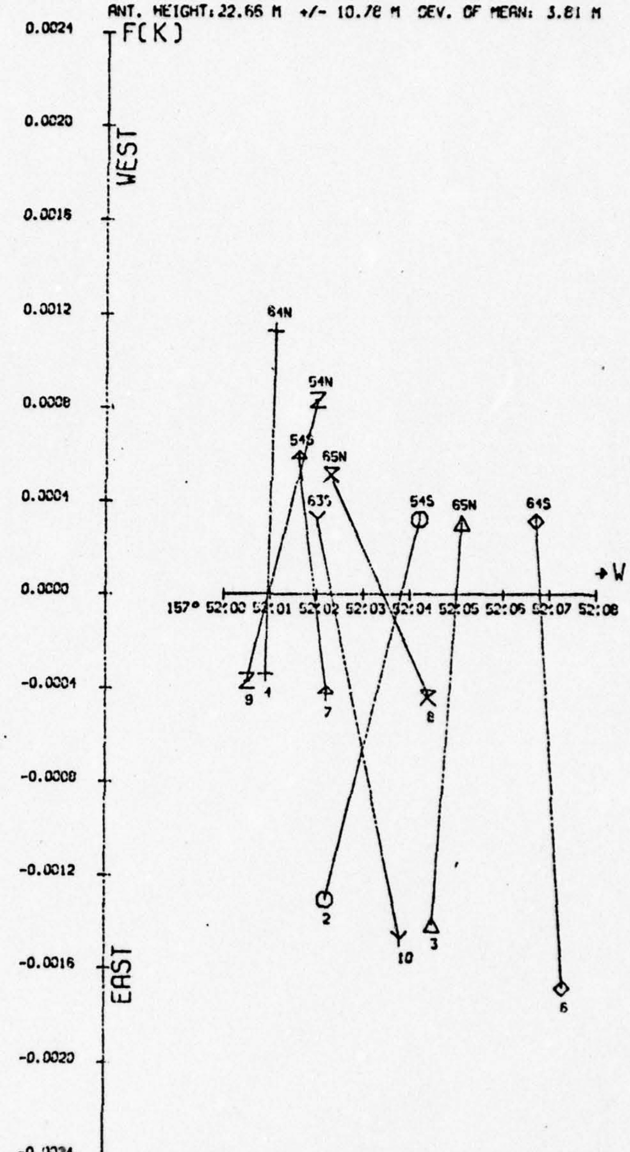
112

LAT.: 21° 18:8025 +/- 0:0301 (55.85 M) DEV. OF MEAN: 0:0067 (12.49 M)
LONG. 157° 52:0256 +/- 0:0222 (38.41 M) 0:0070 (12.15 M)
ANT. HEIGHT: 33.16 M +/- 25.14 M DEV. OF MEAN: 7.95 M



DAY 204-207 1973 KK HNL HT: +24 M # 38 (3σ)

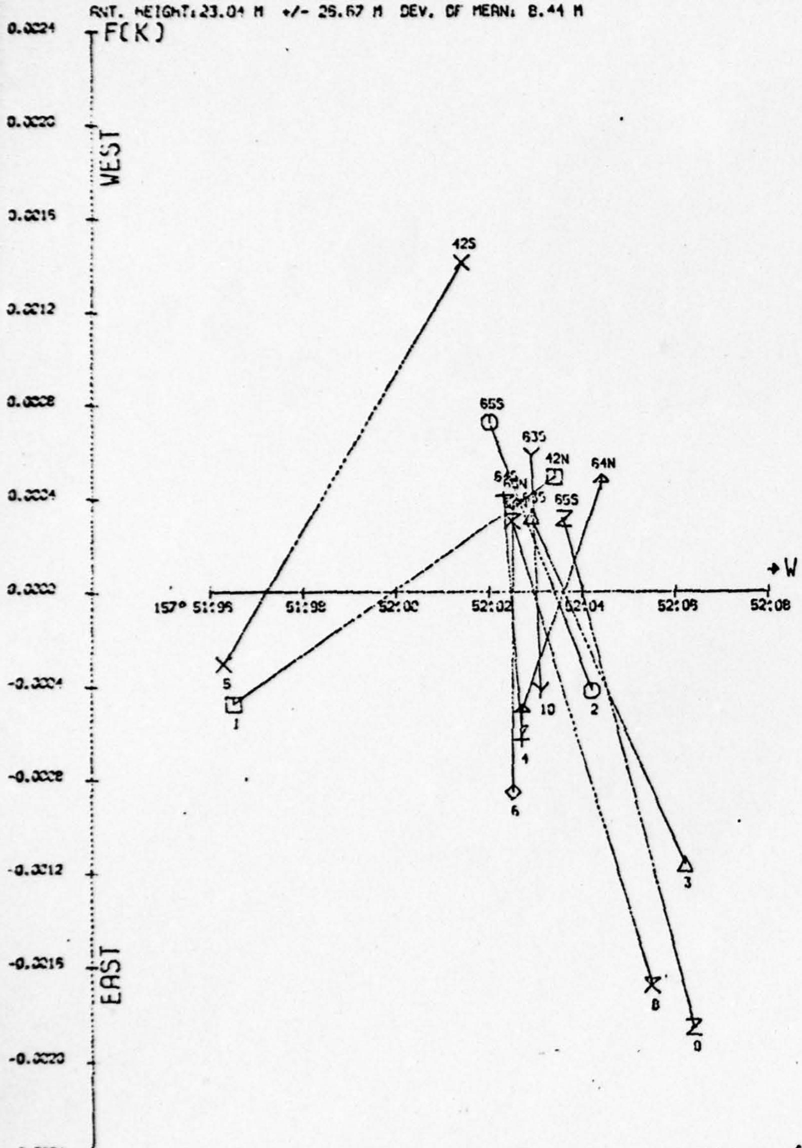
LAT.: 21° 18:8079 +/- 0:0327 (60.50 M) DEV. OF MEAN: 0:0082 (15.15 M)
LONG.. 157° 52:0315 +/- 0:0203 (35.10 M) 0:0072 (12.41 M)
ANT. HEIGHT: 22.66 M +/- 10.78 M DEV. OF MEAN: 3.81 M



DAY 204-207 1973 KK HNL HT: +24 M # 38 2σ

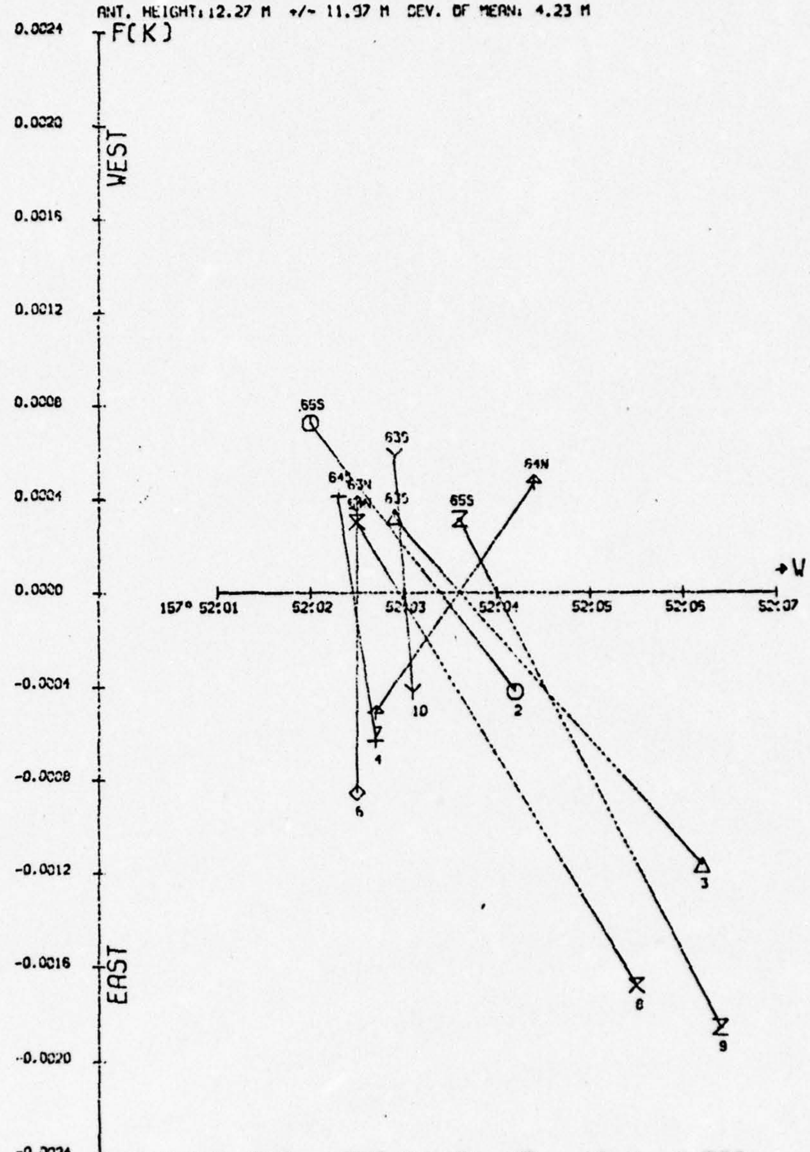
113

LAT.: 21° 18:8137 +/- 0:0181 (33.51 M) DEV. OF MEAN: 0:0040 (7.49 M)
LONG.. 157° 52:0226 +/- 0:0211 (35.44 M) 0:0067 (11.52 M)
ANT. HEIGHT:23.04 M +/- 26.67 M DEV. OF MEAN: 8.44 M



DAY 251-252 1973 KK HNL HT: +19 M # 39A (36)

LAT.: 21° 18:8157 +/- 0:0153 (28.26 M) DEV. OF MEAN: 0:0038 (7.07 M)
LONG.. 157° 52:0319 +/- 0:0055 (9.53 M) 0:0020 (3.37 M)
ANT. HEIGHT:12.27 M +/- 11.97 M DEV. OF MEAN: 4.23 M

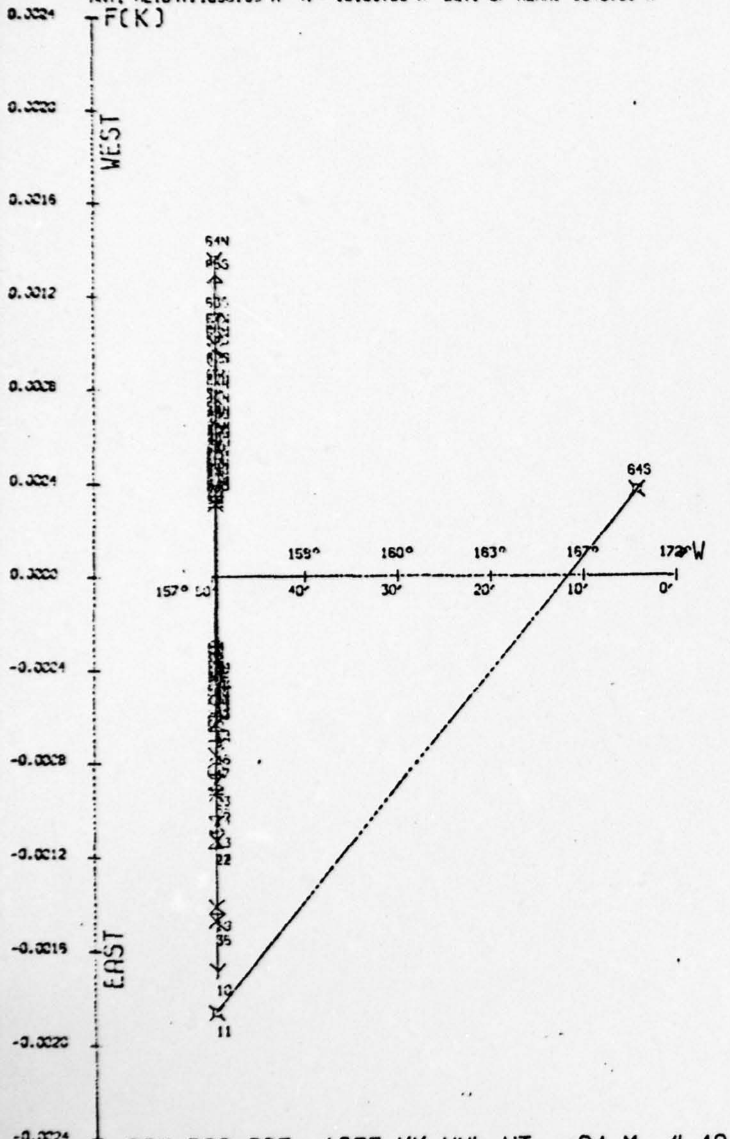


DAY 251-252 1973 KK HNL HT: +19 M # 39A 25

116

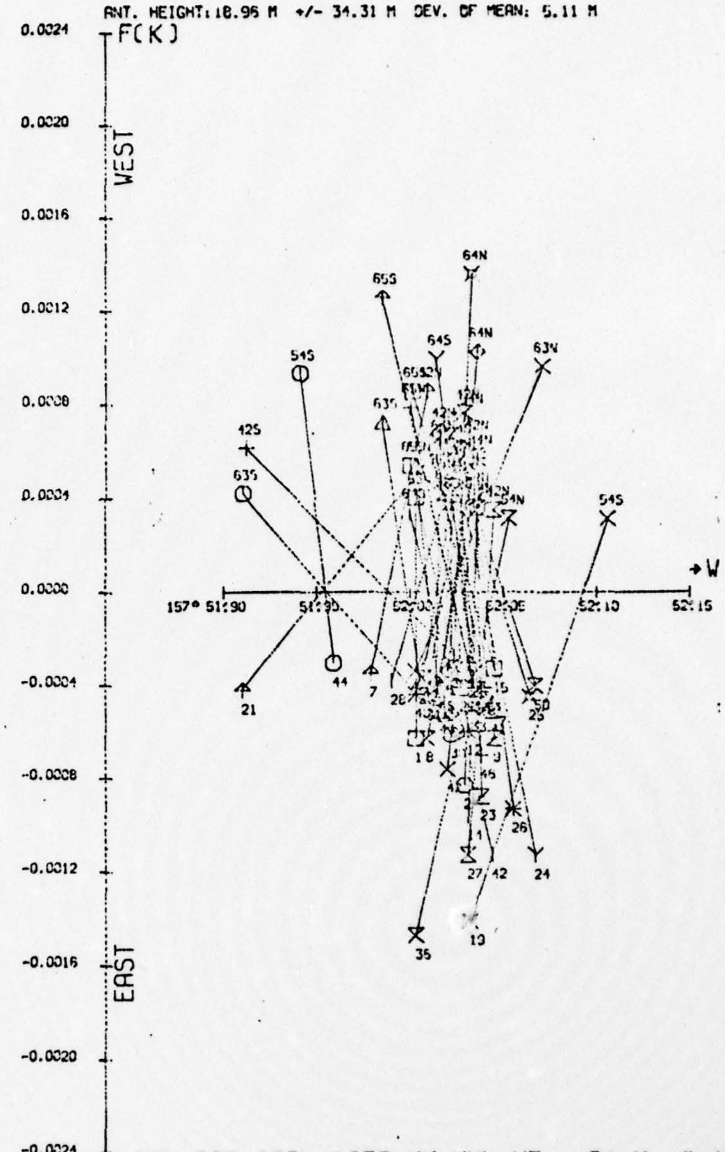
71

LAT.: 21° 20:1790 +/- 13:9437 (25840.55 M) DEV. OF MEAN: 1:3806 (2558.59 M)
LONG.. 157° 55:7553 +/- 26:5166 (45772.46 M) 3:7131 (6409.42 M)
ANT. HEIGHT: 1830.35 M +/- 13163.85 M DEV. OF MEAN: 1843.31 M



DAY 290-297 1973 KK HNL HT: +24 M # 40

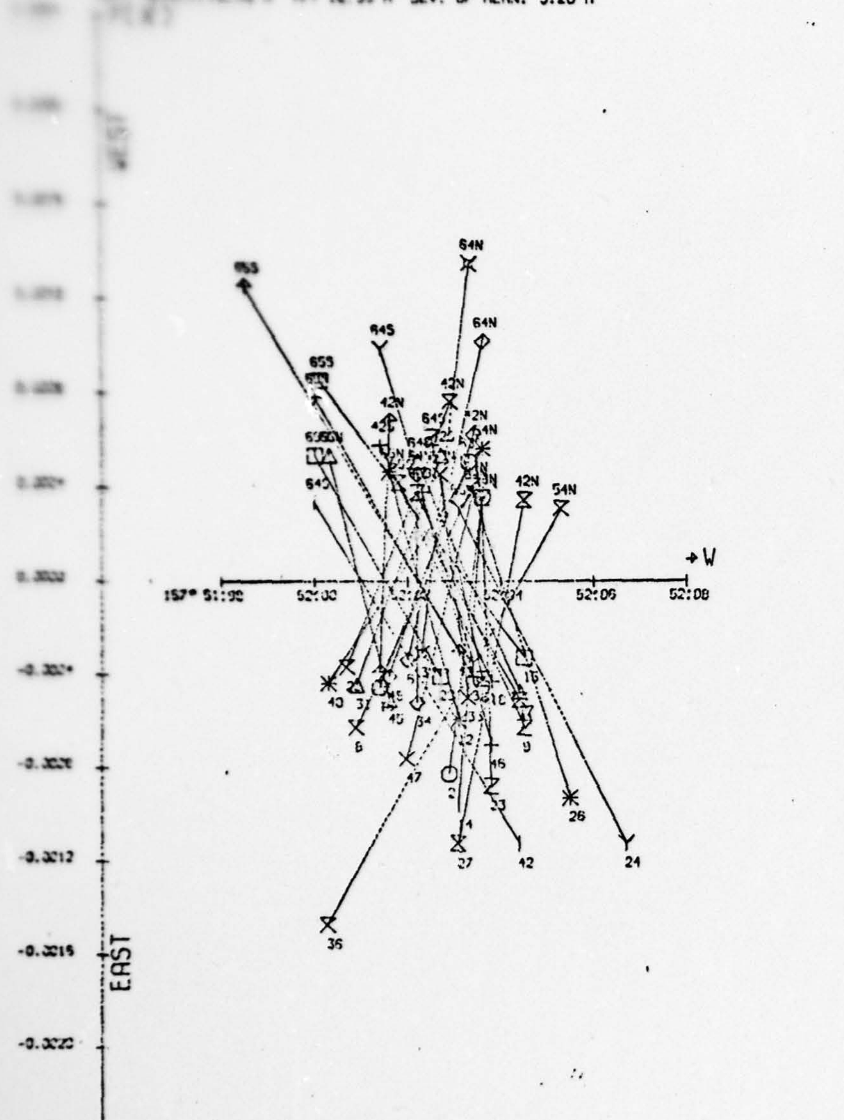
LAT.: 21° 18:7991 +/- 0:0547 (101.37 M) DEV. OF MEAN: 0:0058 (10.63 M)
LONG.. 157° 52:0207 +/- 0:0247 (42.66 M) 0:0037 (6.35 M)
ANT. HEIGHT: 18.96 M +/- 34.31 M DEV. OF MEAN: 5.11 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 35

COMPLØT®

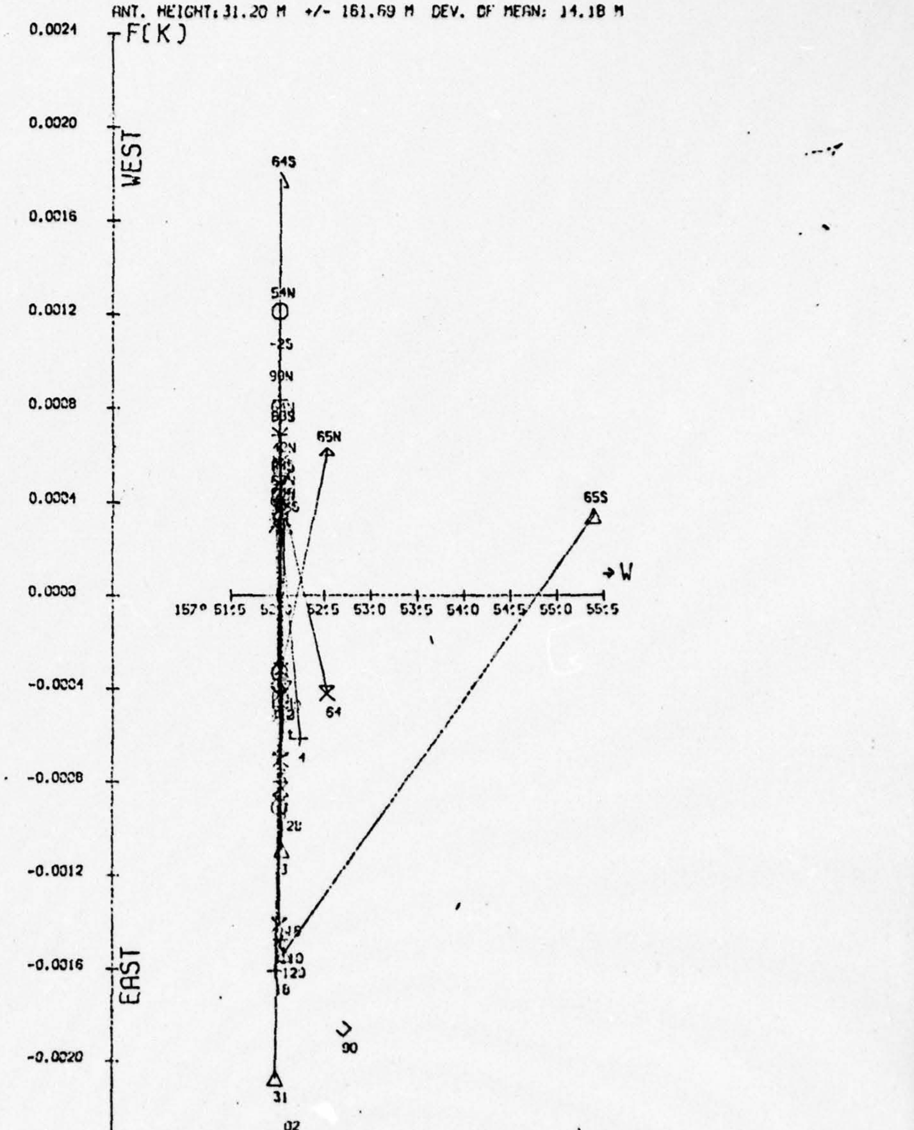
DEV. OF MEAN: 0:0031 (5.83 M)
0:0015 (2.67 M)
DEV. OF MEAN: 3.20 M



DAY 290-297 1973 KK HNL HT: +24 M # 40

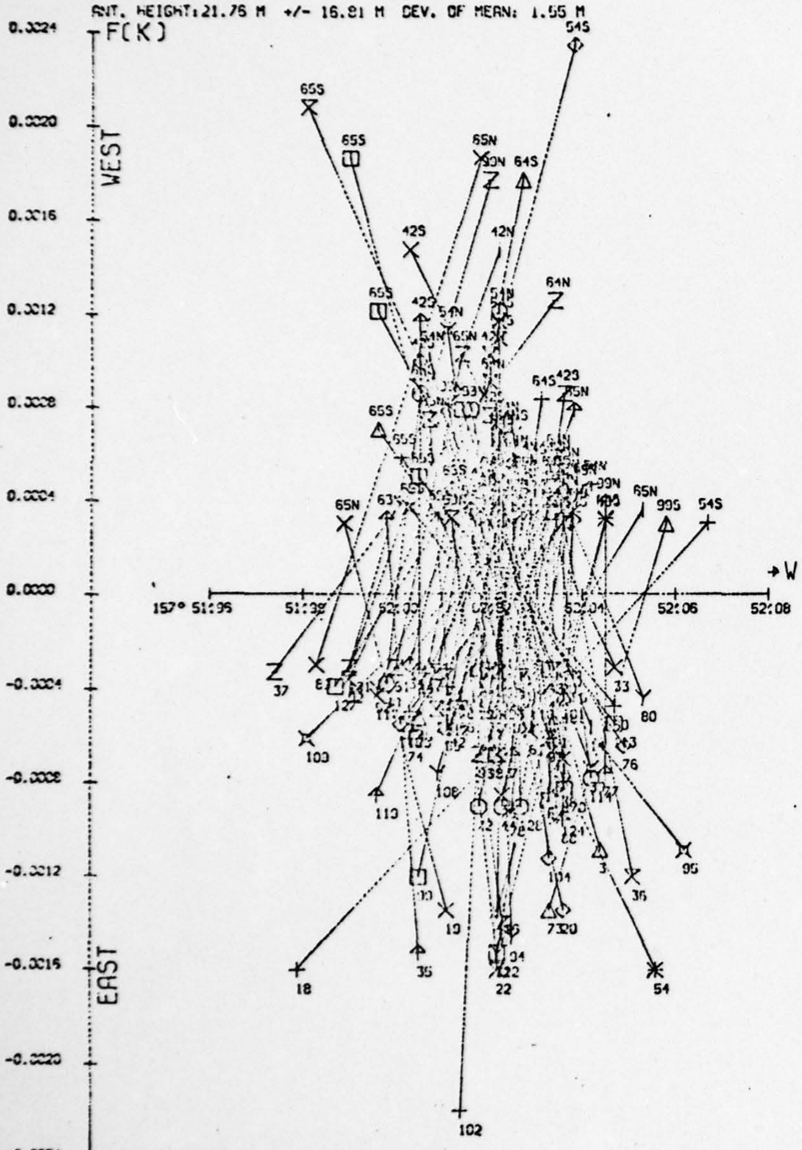
25

LAT.: 21° 18:8186 +/- 0:3023 (560.15 M) DEV. OF MEAN: 0:0187 (34.74 M)
LONG.: 157° 52:0483 +/- 0:2442 (421.65 M) 0:0214 (35.98 M)
ANT. HEIGHT: 31.20 M +/- 161.69 M DEV. OF MEAN: 14.18 M



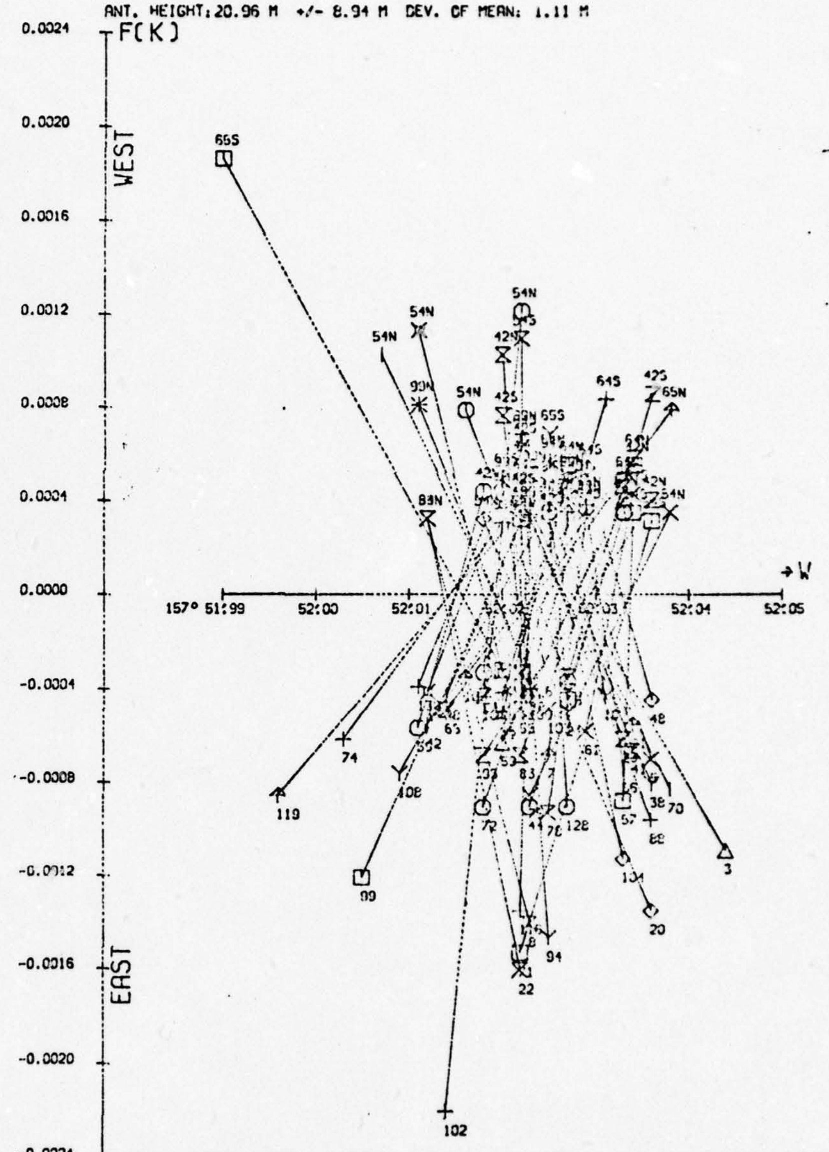
DAY 353-372 1973-4 KK HNL HT: +19.0 M SET 41 ALL

LAT.: 21° 18:8018 +/- 0:0273 (50.66 M) DEV. OF MEAN: 0:0018 (3.31 M)
LONG.. 157° 52:0223 +/- 0:0120 (20.68 M) 0:0011 (1.91 M)
ANT. HEIGHT: 21.76 M +/- 16.81 M DEV. OF MEAN: 1.55 M



DAY 353-372 1973-4 KK HNL HT: +19.0 M SET 41 ALL

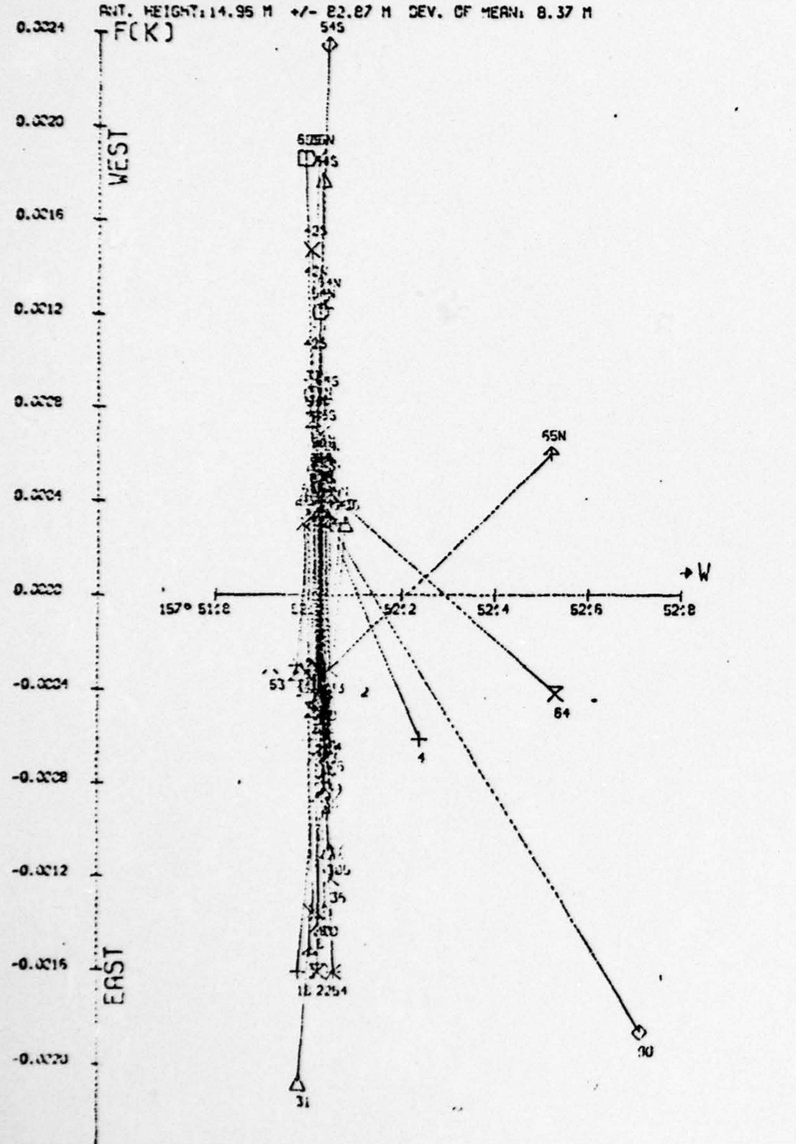
LAT.: 21° 18:8015 +/- 0:0264 (48.89 M) DEV. OF MEAN: 0:0023 (4.23 M)
LONG.. 157° 52:0239 +/- 0:0053 (9.14 M) 0:0007 (1.13 M)
ANT. HEIGHT: 20.96 M +/- 8.94 M DEV. OF MEAN: 1.11 M



DAY 353-372 1973-4 KK HNL HT: +19.0 M SET 41 ALL

16

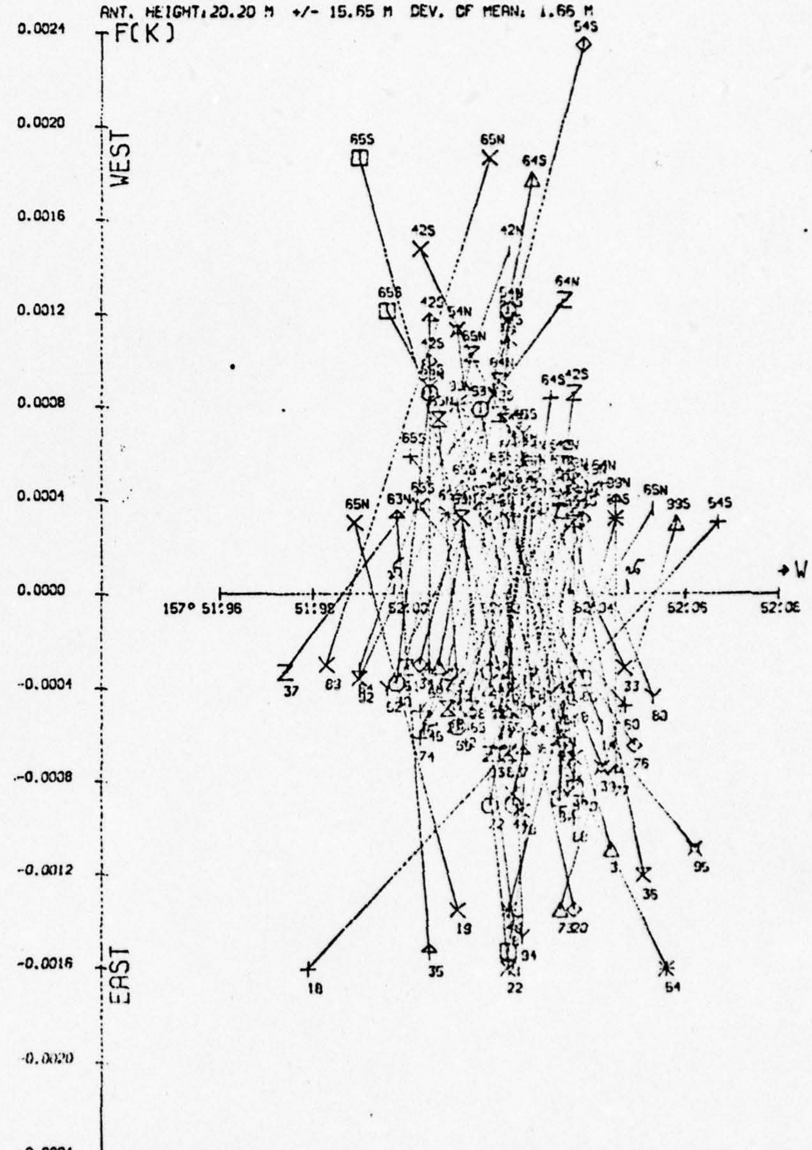
LAT.: 21° 18:8010 +/- 0:0307 (56.90 M) DEV. OF MEAN: 0:0022 (4.06 M)
LONG.. 157° 52:0284 +/- 0:0401 (69.18 M) 0:0040 (6.99 M)
ANT. HEIGHT: 14.95 M +/- 82.87 M DEV. OF MEAN: 8.37 M



DAY 353-365 1973 KK HON HT: +19.0 M SET 41A

19 Aug 76 F. Ray

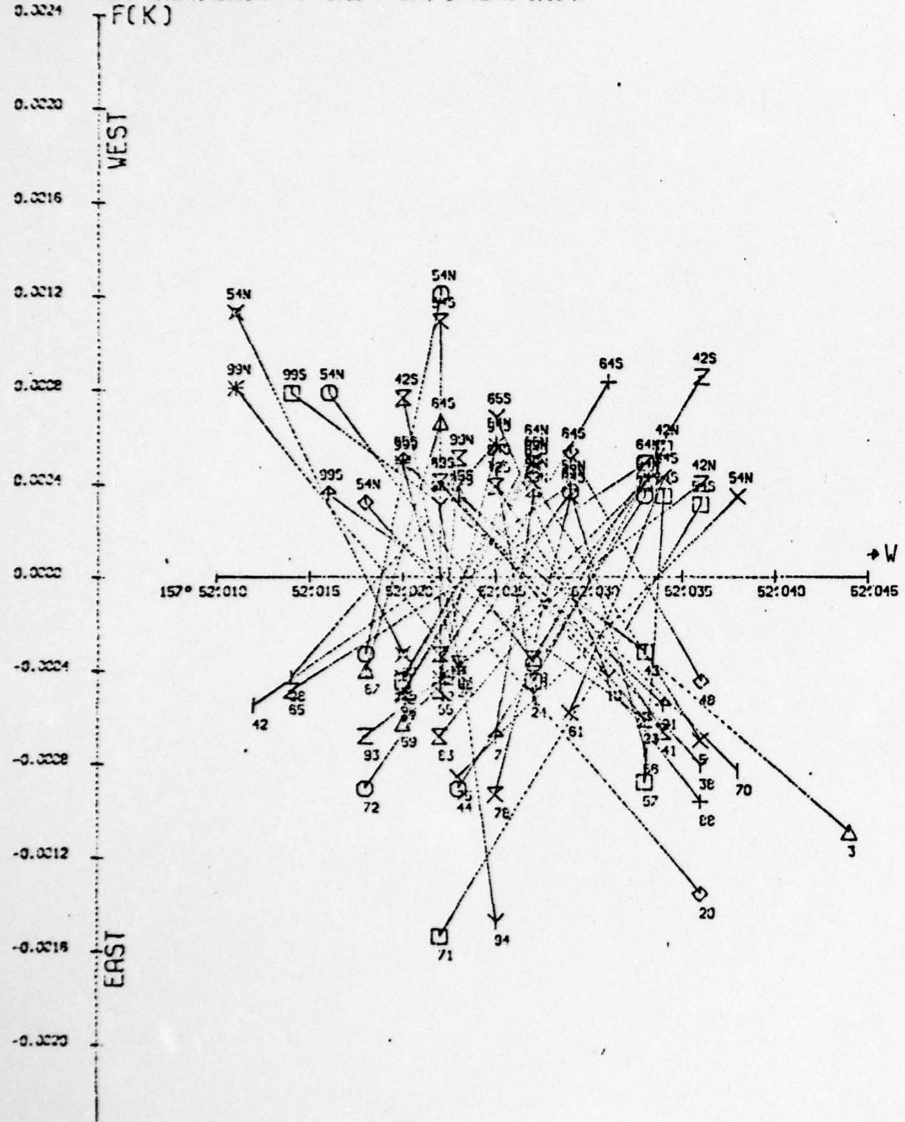
LAT.: 21° 18:8015 +/- 0:0276 (51.14 M) DEV. OF MEAN: 0:0021 (3.83 M)
LONG.. 157° 52:0227 +/- 0:0126 (21.79 M) 0:0013 (2.31 M)
ANT. HEIGHT: 20.20 M +/- 15.65 M DEV. OF MEAN: 1.66 M



DAY 353-365 1973 KK HON HT: +19.0 M SET 41A

17 18

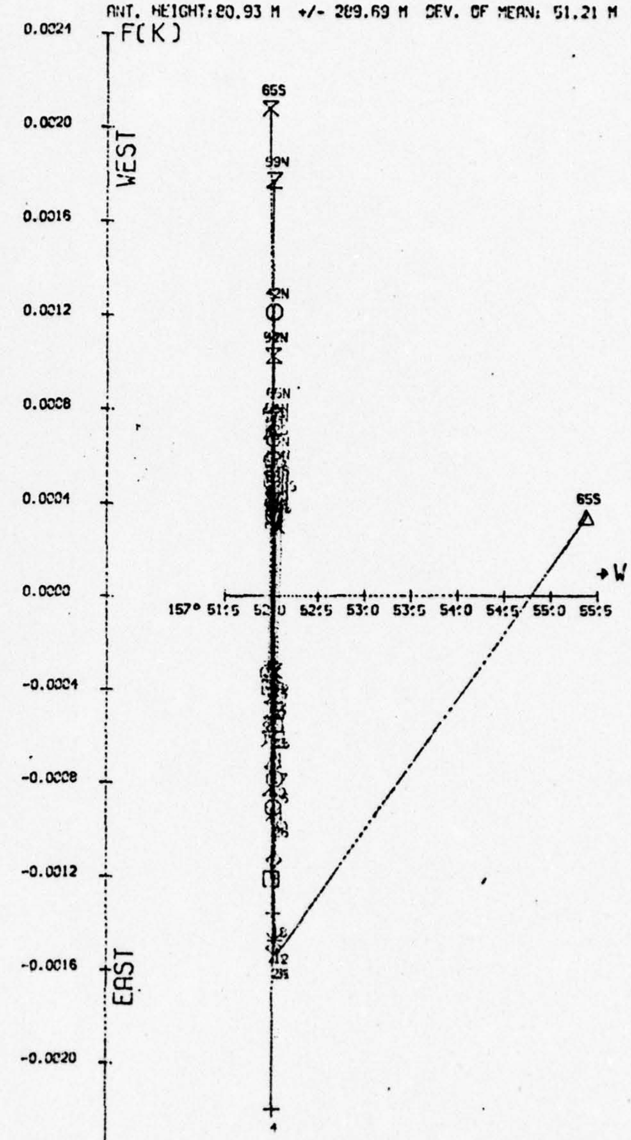
LAT.. 21° 18:8030 +/- 0:0251 (46.56 M) DEV. OF MEAN: 0:0026 (4.80 M)
LONG.. 157° 52:0259 +/- 0:0042 (7.33 M) 0:0006 (1.07 M)
ANT. HEIGHT: 19.20 M +/- 8.93 M DEV. OF MEAN: 1.30 M



DAY 353-365 1973 KK HON HT: -19.0 M SET 41A

20

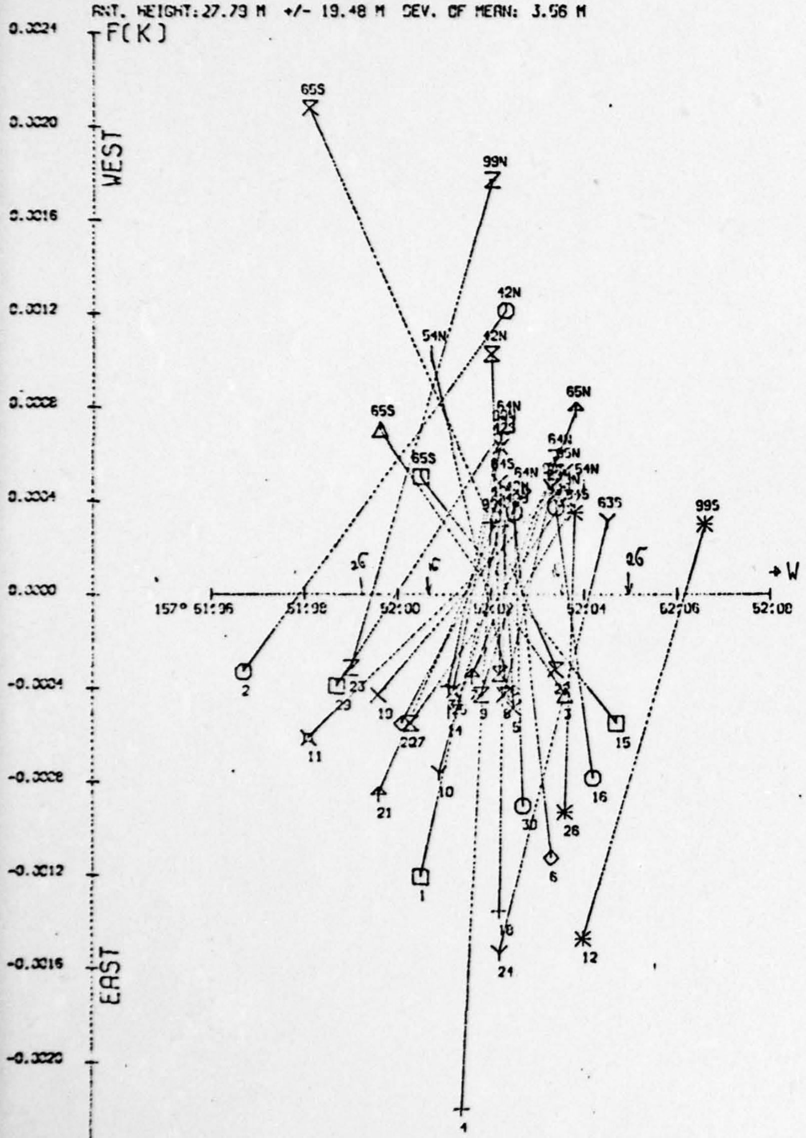
LAT.: 21° 18:8721 +/- 0:6073 (1125.47 M) DEV. OF MEAN: 0:0759 (140.60 M)
LONG.. 157° 52:1092 +/- 0:4880 (842.44 M) 0:0063 (148.92 M)
ANT. HEIGHT: 80.93 M +/- 289.69 M DEV. OF MEAN: 51.21 M



DAY 1-7 1974 KK HON HT: -19.0 M SET 41B

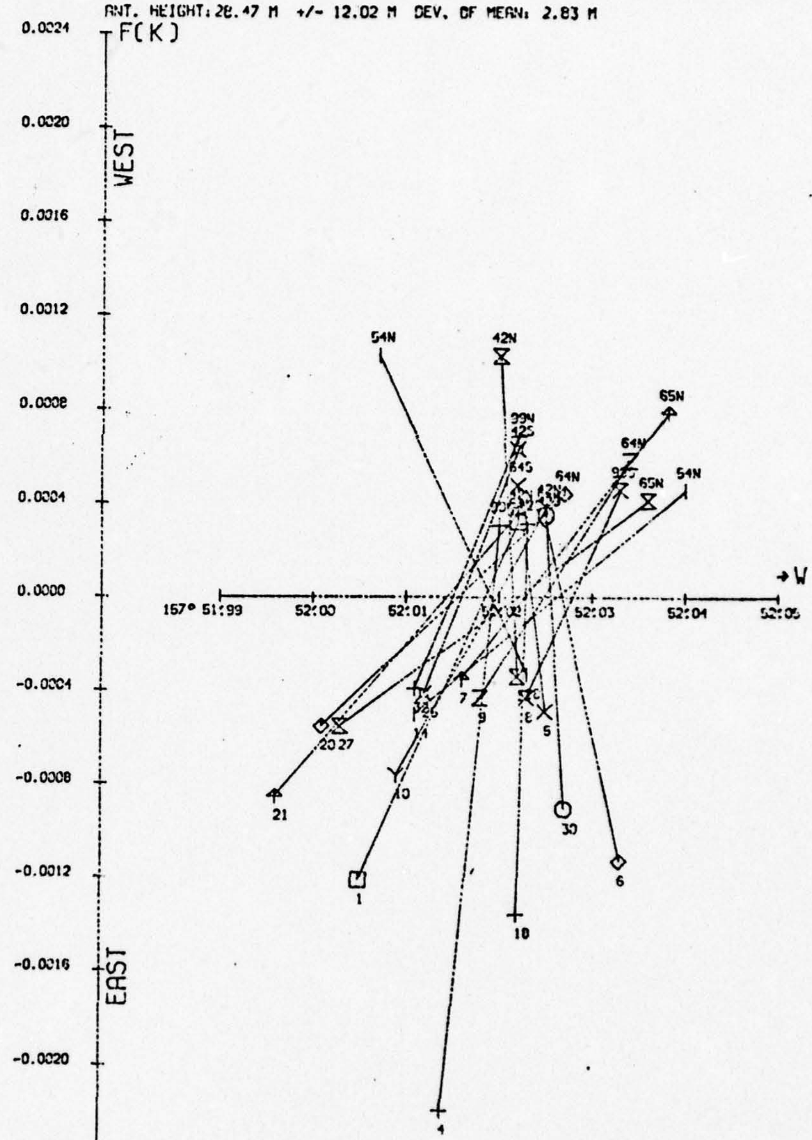
CØMPLØT*

LAT.: 21° 18:7952 +/- 0:0550 (101.95 M) DEV. OF MEAN: 0:0071 (13.16 M)
LONG.. 157° 52:0203 +/- 0:0144 (24.78 M) 0:0026 (4.52 M)
ANT. HEIGHT: 27.73 M +/- 19.48 M DEV. OF MEAN: 3.56 M



DAY 1-7 1974 KK HON HT: +19.0 M SET 41B 3σ

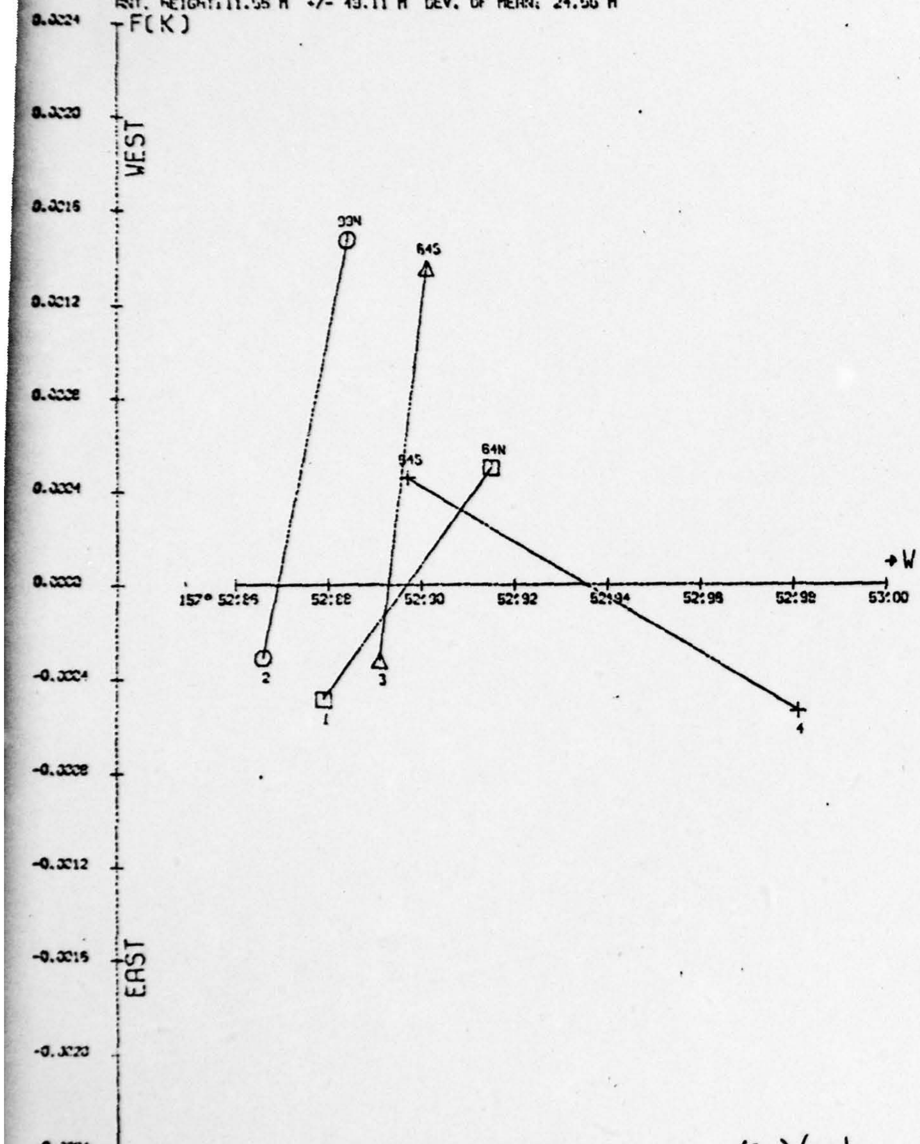
LAT.: 21° 18:8005 +/- 0:0267 (49.39 M) DEV. OF MEAN: 0:0044 (8.23 M)
LONG.: 157° 52:0211 +/- 0:0042 (7.34 M) 0:0010 (1.73 M)
ANT. HEIGHT: 28.47 M +/- 12.02 M DEV. OF MEAN: 2.83 M



DAY 1-7 1974 KK HON HT: +19.0 M SET 41B 2σ

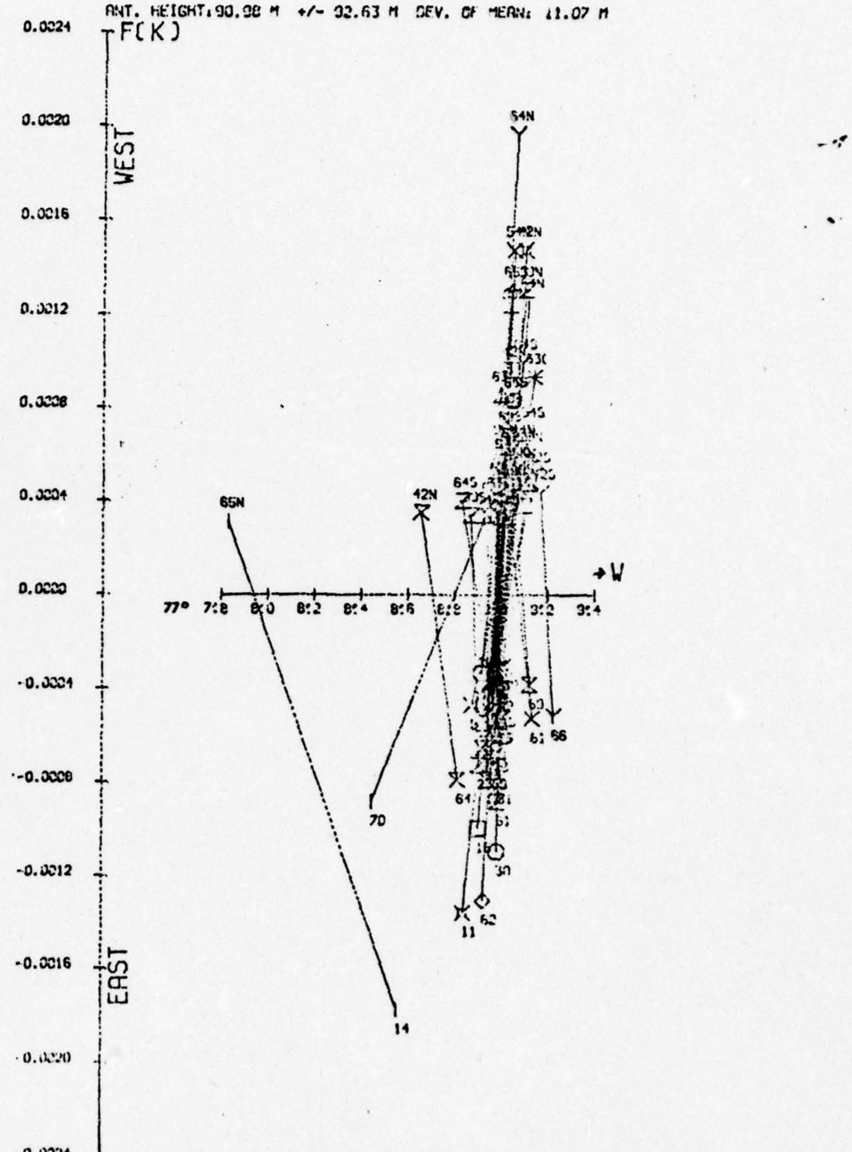
118

LAT.: 21° 19:0671 +/- 0:0263 (48.69 M) DEV. OF MEAN: 0:0093 (17.21 M)
LONG.. 157° 52:8986 +/- 0:0275 (47.49 M) 0:0138 (23.74 M)
ANT. HEIGHT: 11.56 M +/- 43.11 M DEV. OF MEAN: 24.56 M



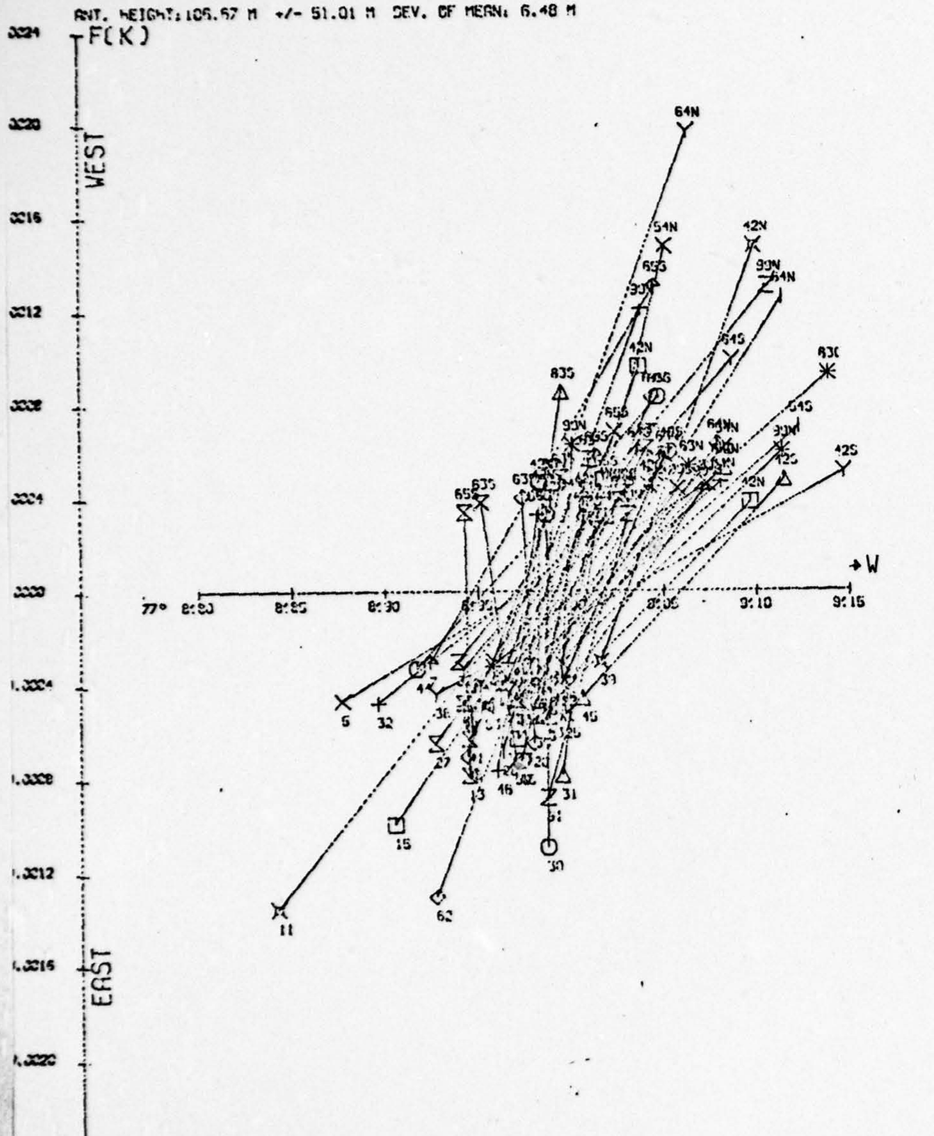
DAY 9 1974 KK HNL HT +19 M # 42 (2σ)(3σ)

LAT.: -12° 3:3110 +/- 0:1359 (251.60 M) DEV. OF MEAN: 0:0115 (21.26 M)
LONG.. 77° 8:9766 +/- 0:1382 (250.51 M) 0:0165 (29.94 M)
ANT. HEIGHT: 90.98 M +/- 92.63 M DEV. OF MEAN: 11.07 M



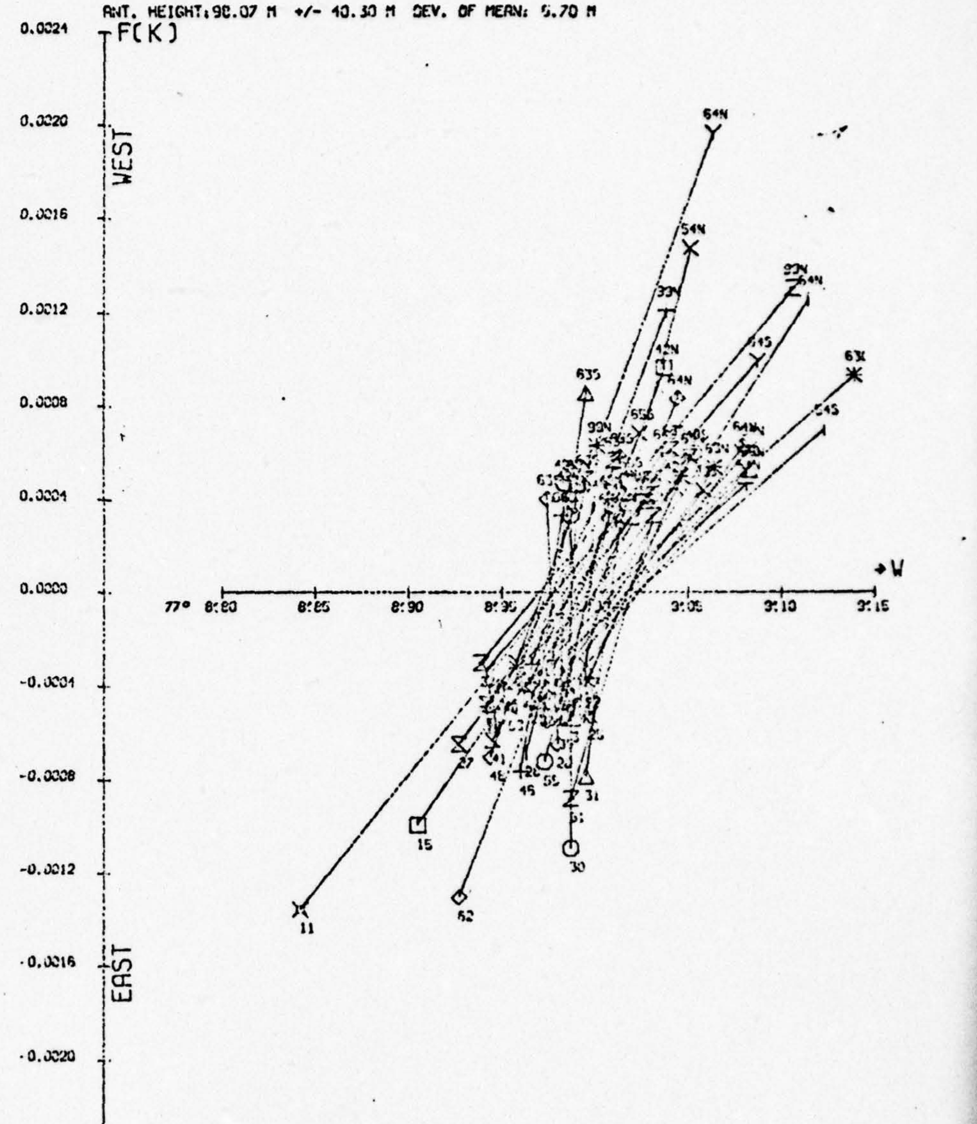
DAY 72-90 1974 KK CALLAO SITE 'A' HT: +38 M # 43

LAT.: -12° 3:3018 +/- 0:0505 (93.67 M) DEV. OF MEAN: 0:0046 (8.41 M)
LONG.. 77° 8:9364 +/- 0:0232 (41.97 M) 0:0029 (5.33 M)
ANT. HEIGHT: 105.67 M +/- 51.01 M DEV. OF MEAN: 6.48 M



DAY 72-90 1974 KK CALLAO SITE 'A' HT: +38 M # 43 3σ

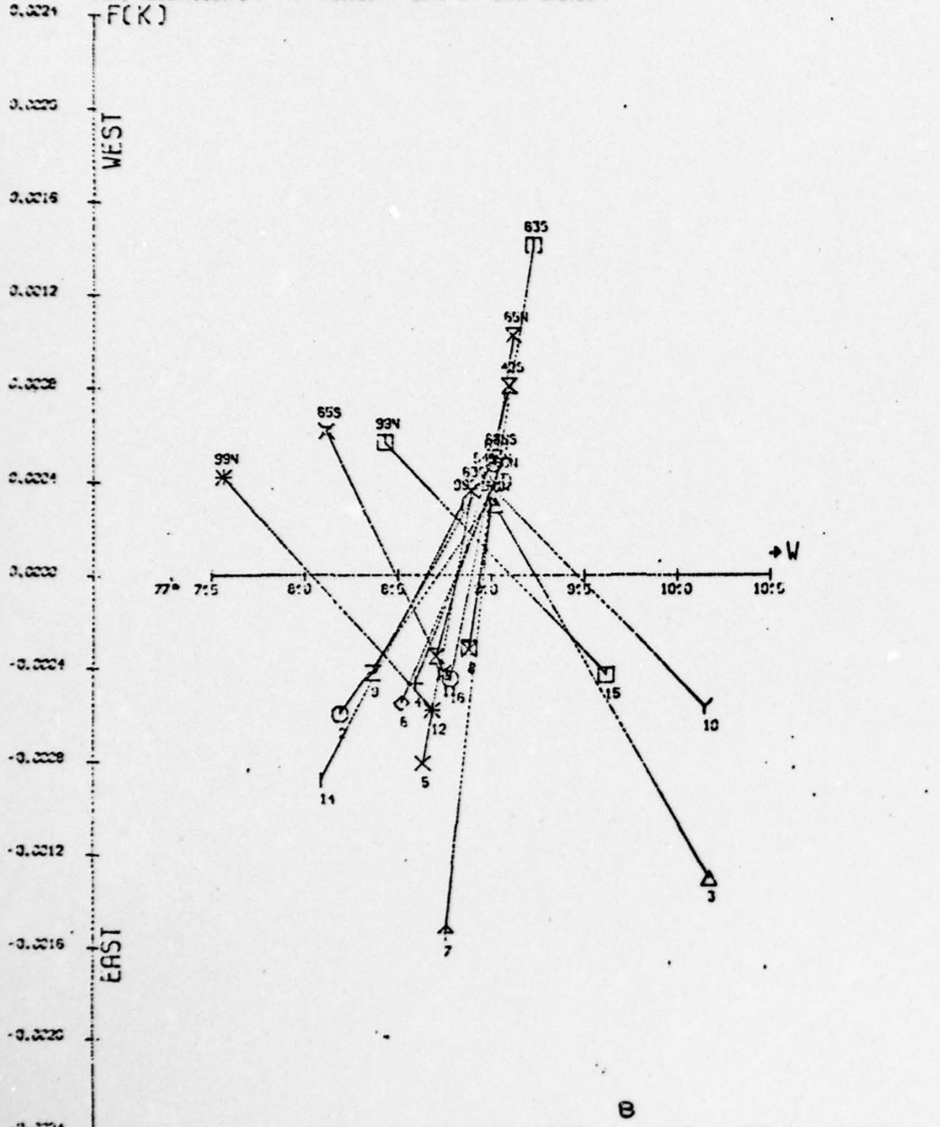
LAT.: -12° 3:2286 +/- 0:0459 (84.86 M) DEV. OF MEAN: 0:0046 (8.43 M)
LONG.. 77° 8:9958 +/- 0:0153 (27.73 M) 0:0022 (3.93 M)
ANT. HEIGHT: 90.07 M +/- 40.30 M DEV. OF MEAN: 5.70 M



DAY 72-90 1974 KK CALLAO SITE 'A' HT: +38 M # 43 2

and pd 1 Sept 76

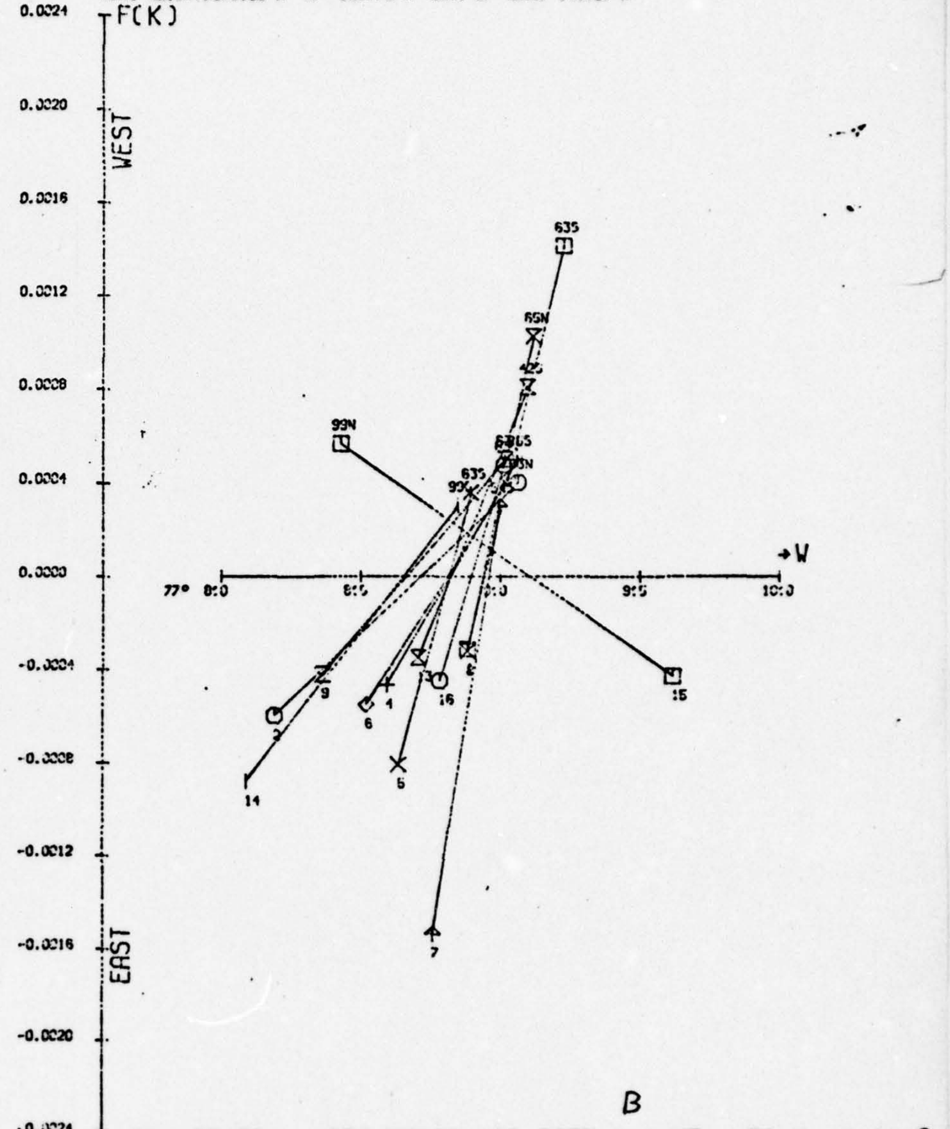
LAT.: -12° 3:1626 +/- 0:4836 (896.38 M) DEV. OF MEAN: 0:0856 (158.44 M)
LONG.: 77° 8:8355 +/- 0:3169 (574.40 M) 0:0792 (143.60 M)
ANT. HEIGHT: 18.69 M +/- 691.21 M DEV. OF MEAN: 172.80 M



DAY 90-99 1974 KK CALLAO SITE ' ' HT: +38 M # 44

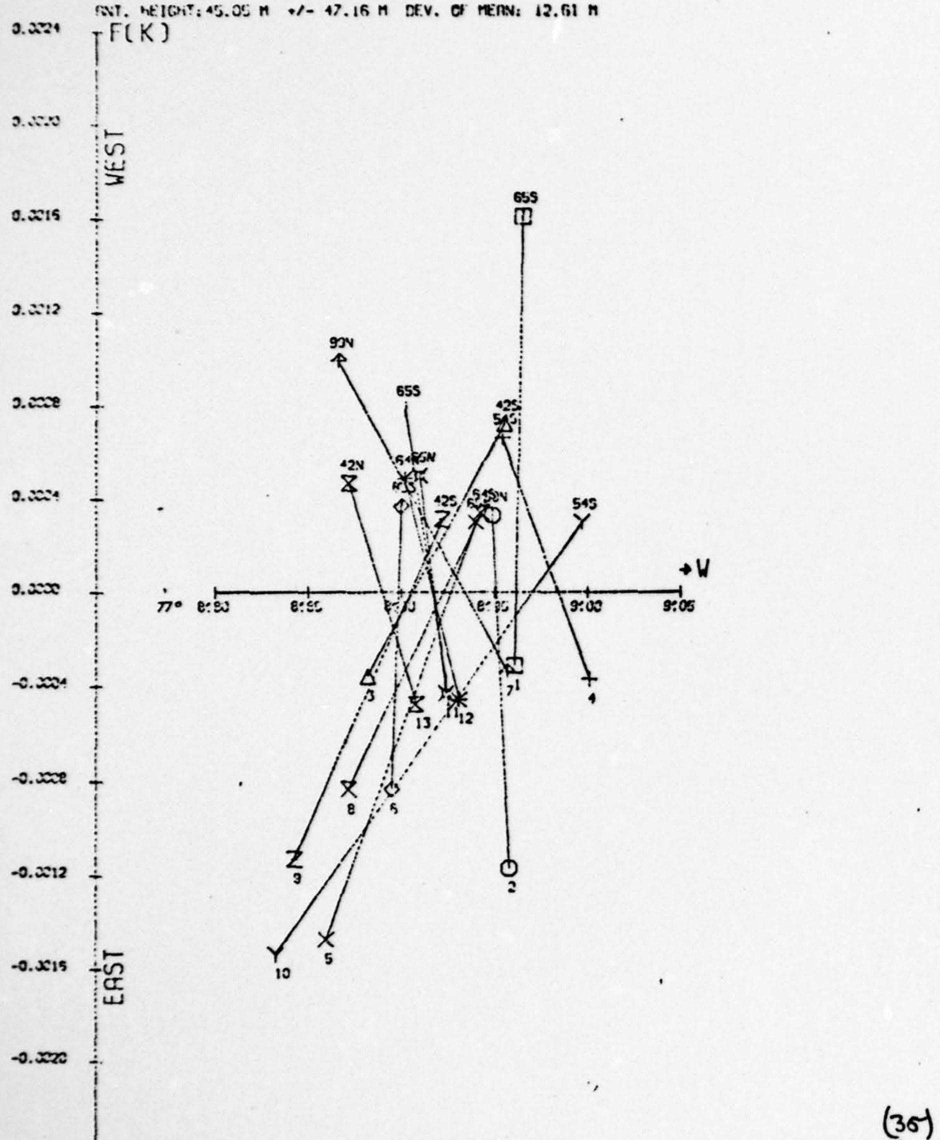
1 Sept 76

LAT.: -12° 3:2063 +/- 0:3131 (580.17 M) DEV. OF MEAN: 0:0639 (118.43 M)
LONG.: 77° 8:8452 +/- 0:1324 (239.97 M) 0:0382 (69.25 M)
ANT. HEIGHT: 309.90 M +/- 508.79 M DEV. OF MEAN: 146.87 M



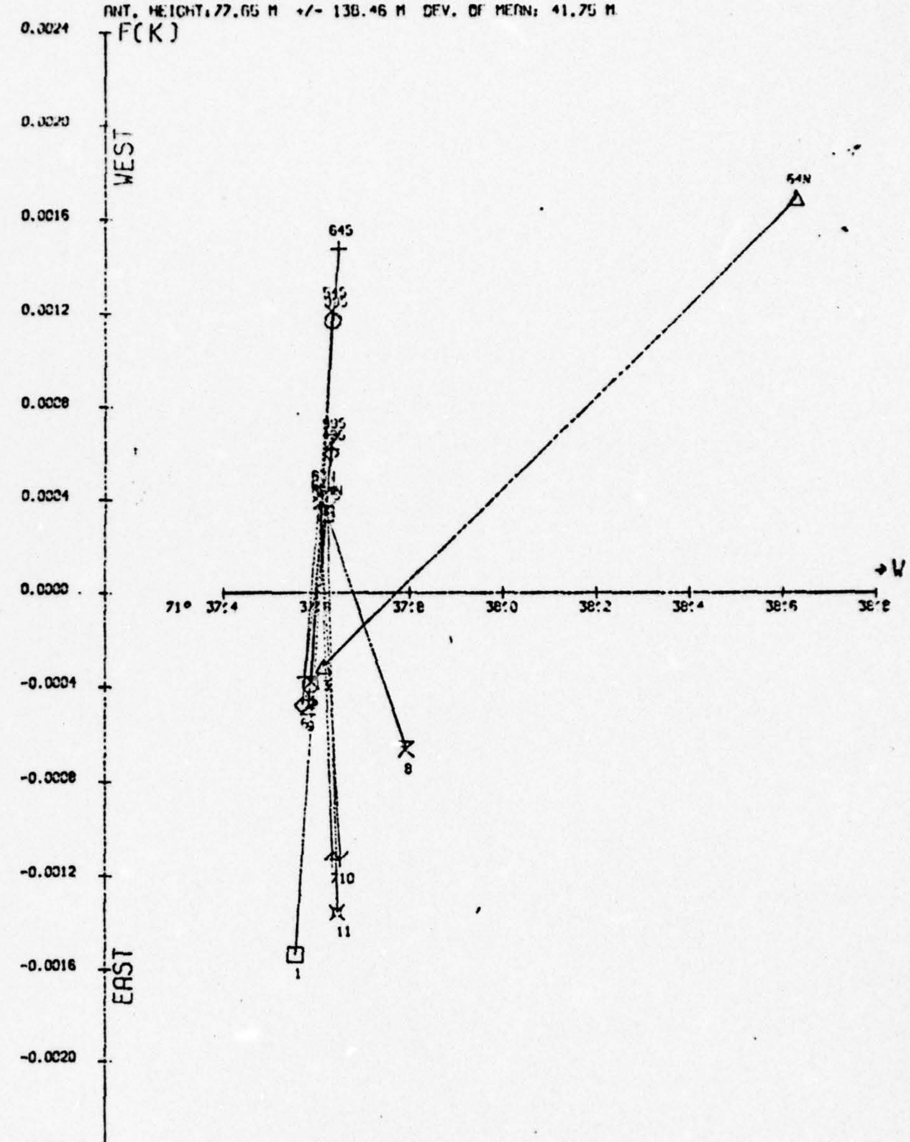
DAY 90-99 1974 KK CALLAO SITE ' ' HT: +38 M # 44 2σ

LAT.. -12° 3:2173 +/- 0:0402 (91.10 M) DEV. OF MEAN: 0:0093 (17.22 M)
LONG.. 77° 9:0286 +/- 0:0282 (51.16 M) 0:0075 (13.57 M)
ANT. HEIGHT: 45.05 M +/- 47.16 M DEV. OF MEAN: 12.61 M



DAY 99-101 1974 KK CALLAO SITE 'D' HT: +38 M # 45 (3σ) (2σ)

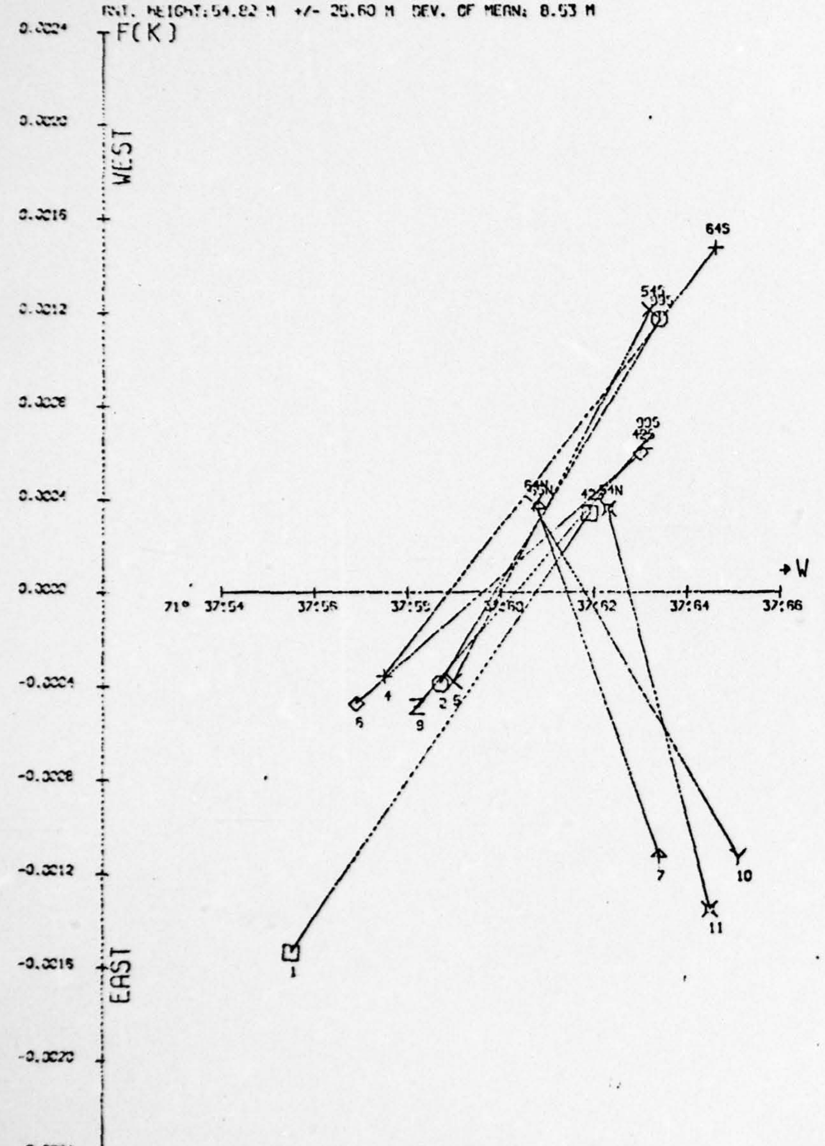
LAT.: -33° 2:0166 +/- 0:0350 (64.80 M) DEV. OF MEAN: 0:0075 (13.83 M)
LONG.. 71° 37:6279 +/- 0:0542 (84.17 M) 0:0163 (25.38 M)
ANT. HEIGHT: 77.65 M +/- 138.46 M DEV. OF MEAN: 41.75 M



DAY 142-146 1974 KK VALPARAISO HT: +39 M # 46 (3σ)

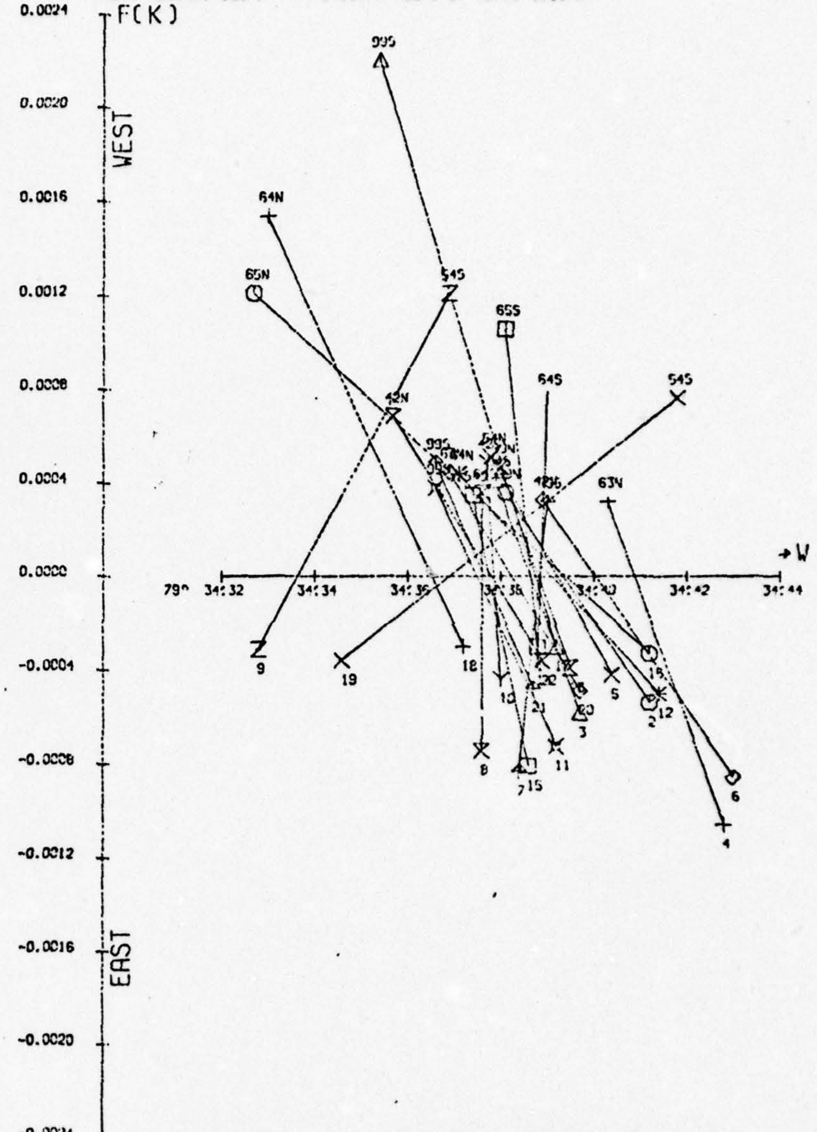
(2)

LAT.: -33° 2:0068 +/- 0:0256 (47.48 M) DEV. OF MEAN: 0:0060 (11.19 M)
LONG. 71° 37:6060 +/- 0:0121 (18.78 M) 0:0040 (6.26 M)
ANT. HEIGHT:54.82 M +/- 25.60 M DEV. OF MEAN: 8.53 M



DAY 142-146 1974 KK VALPARAISO HT: +39 M # 46 2σ

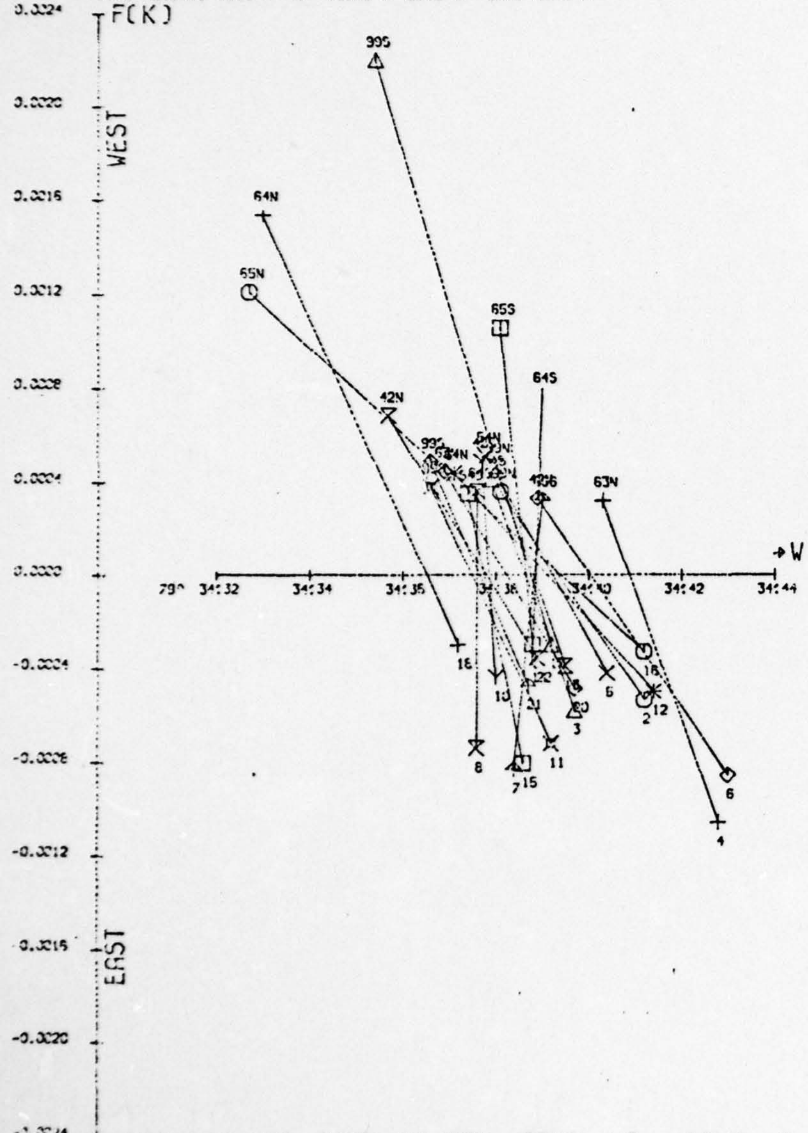
LAT.: 8° 57:1147 +/- 0:0433 (80.31 M) DEV. OF MEAN: 0:0065 (12.11 M)
LONG.. 79° 34:3827 +/- 0:0146 (26.47 M) 0:0031 (5.64 M)
ANT. HEIGHT:4.80 M +/- 24.89 M DEV. OF MEAN: 5.31 M



DAY 168-172 1974 KK PAN. CANAL HT: +19 M # 47

76

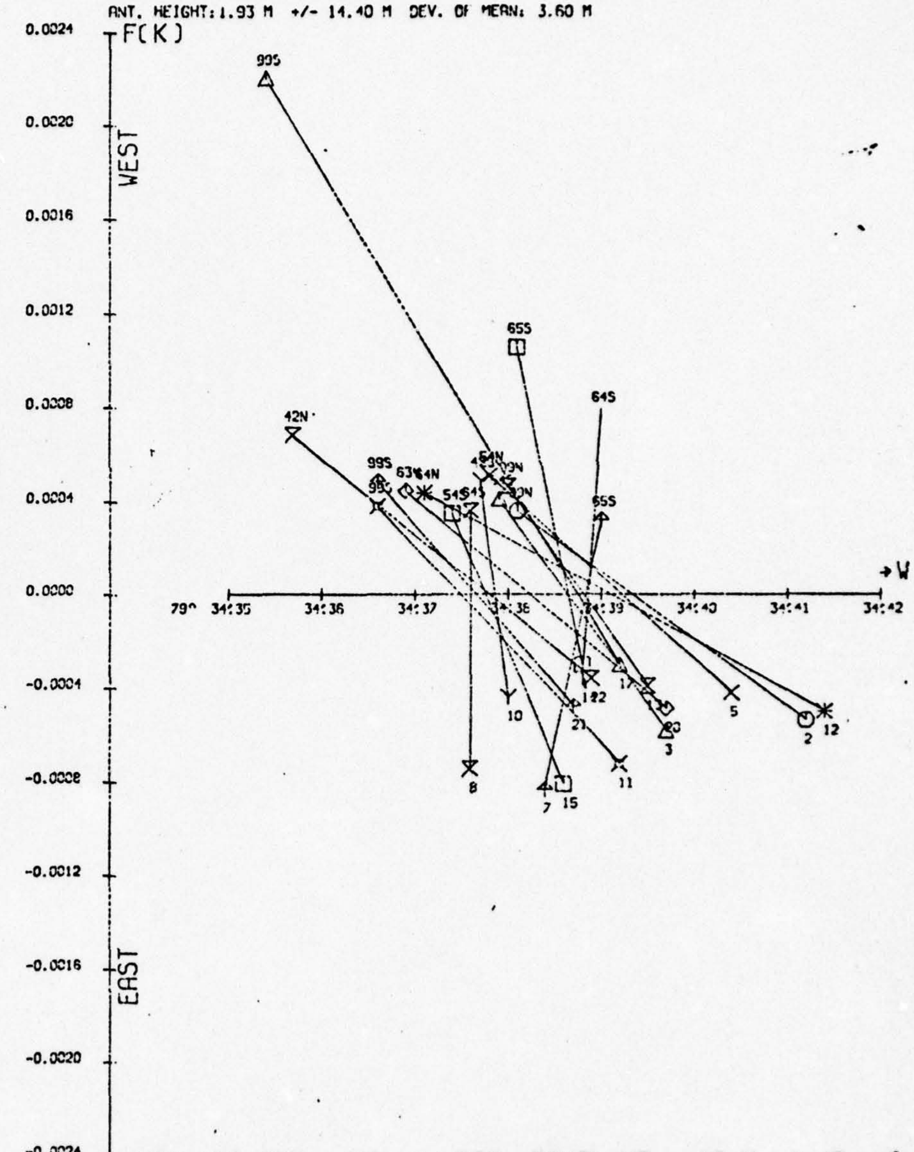
LAT.. 8° 57:1152 +/- 0:0438 (81.08 M) DEV. OF MEAN: 0:0069 (12.82 M)
LONG. 79° 34:3857 +/- 0:0080 (18.20 M) 0:0022 (4.07 M)
ANT. HEIGHT: -1.11 M +/- 15.63 M DEV. OF MEAN: 3.50 M



DAY 168-172 1974 KK PAN. CANAL HT: +19 M # 47 30

123

LAT.: 8° 57:1240 +/- 0:0348 (64.54 M) DEV. OF MEAN: 0:0062 (11.41 M)
LONG.. 79° 34:3841 +/- 0:0063 (11.55 M) 0:0016 (2.83 M)
ANT. HEIGHT: 1.93 M +/- 14.40 M DEV. OF MEAN: 3.60 M



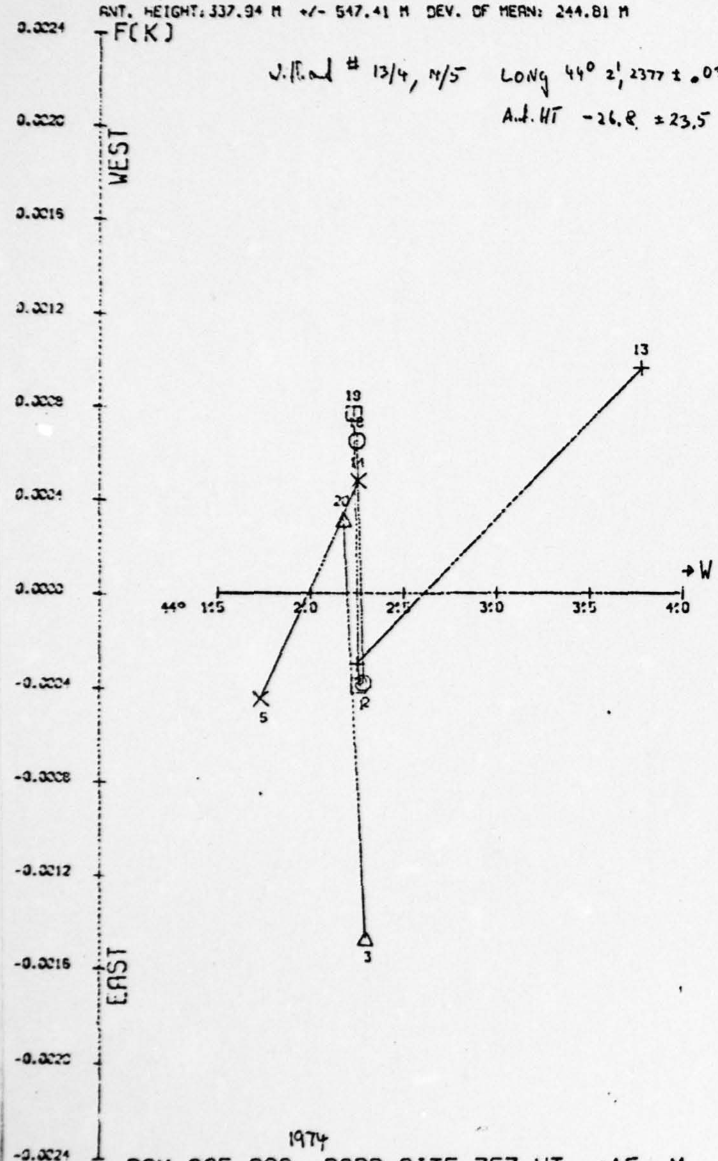
DAY 168-172 1974 KK PAN. CANAL HT: +19 M # 47 20

Group II

:39

LAT.: 10° 54:9880 +/- 0:2335 (432.82 M) DEV. OF MEAN: 0:0739 (136.87 M)
LONG.. 44° 2:2521 +/- 0:2254 (410.17 M) 0:1008 (183.43 M)
ANT. HEIGHT: 337.94 M +/- 547.41 M DEV. OF MEAN: 244.81 M

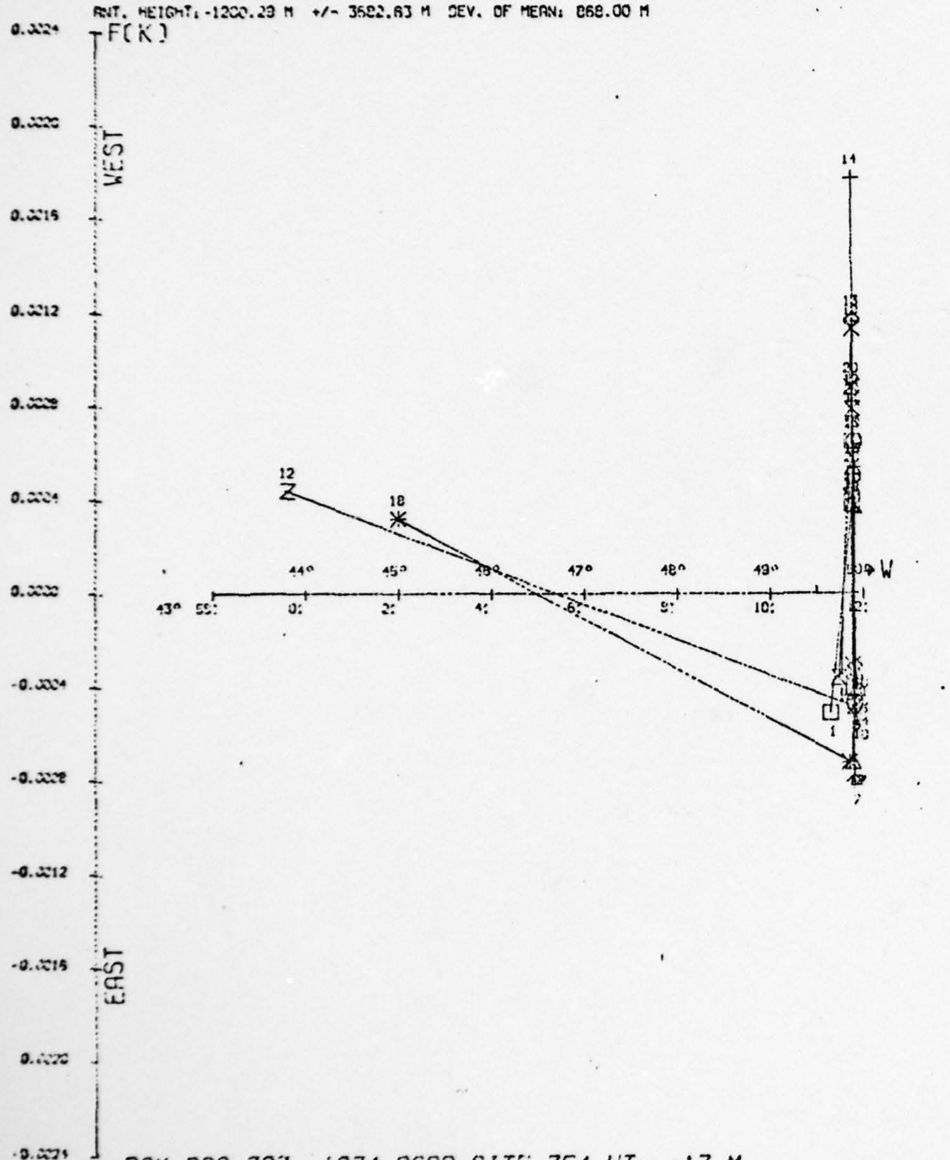
J.R.L # 13/4, M/5 Long 44° 2!2377 ± .0387 ± .0123
A.d.HT -26.8 ± 23.5 ± 13.6



1974
DAY 295-296 DSDP SITE 353 HT: +15 M (2σ)

1 Sept. 76

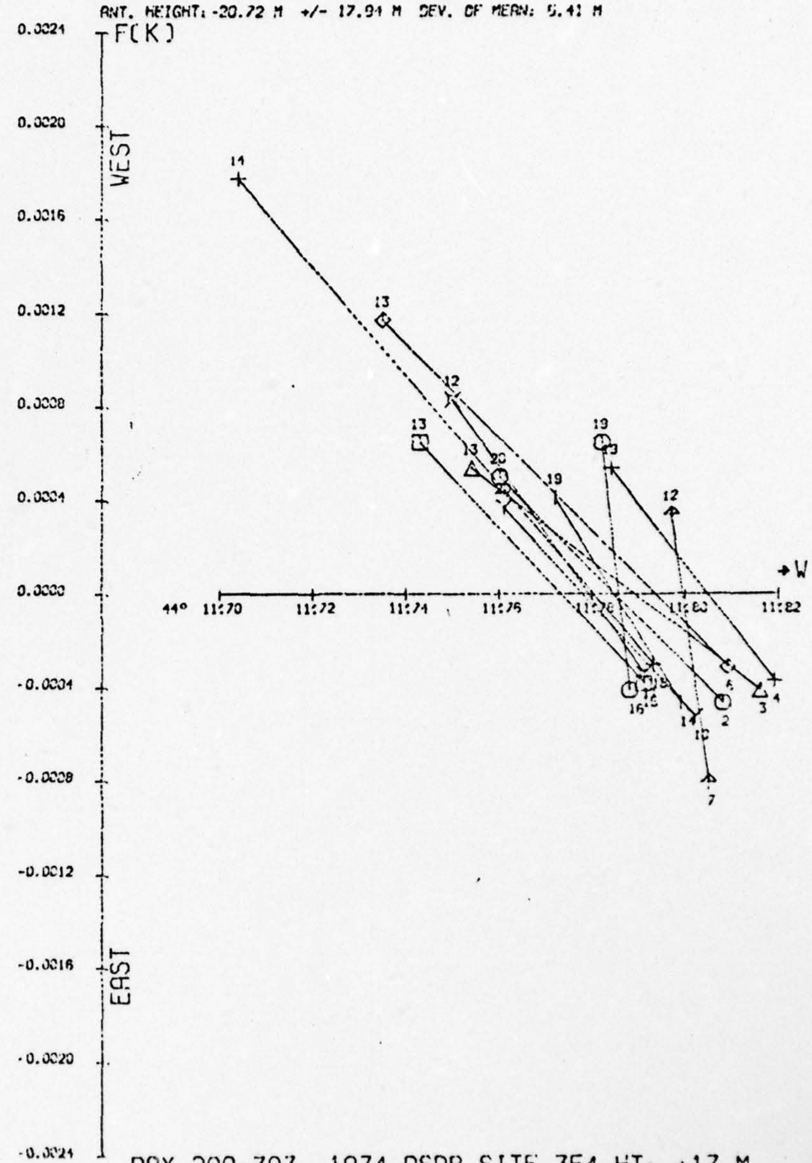
LAT.. 5° 58:6938 +/- 28:0802 (52073.37 M) DEV. OF MEAN: 4:6832 (8678.90 M)
LONG.. 44° 11:0102 +/- 2:1261 (3918.60 M) 0:5011 (923.62 M)
ANT. HEIGHT: -1200.29 M +/- 3582.63 M DEV. OF MEAN: 868.00 M



DAY 299-303 1974 DSDP SITE 354 HT: +17 M

1 Sept. 76

LAT.: 5° 53:9534 +/- 0:0373 (69.05 M) DEV. OF MEAN: 0:0079 (14.72 M)
LONG.. 44° 11:7866 +/- 0:0095 (17.56 M) 0:0028 (5.23 M)
ANT. HEIGHT: -20.72 M +/- 17.94 M DEV. OF MEAN: 5.41 M

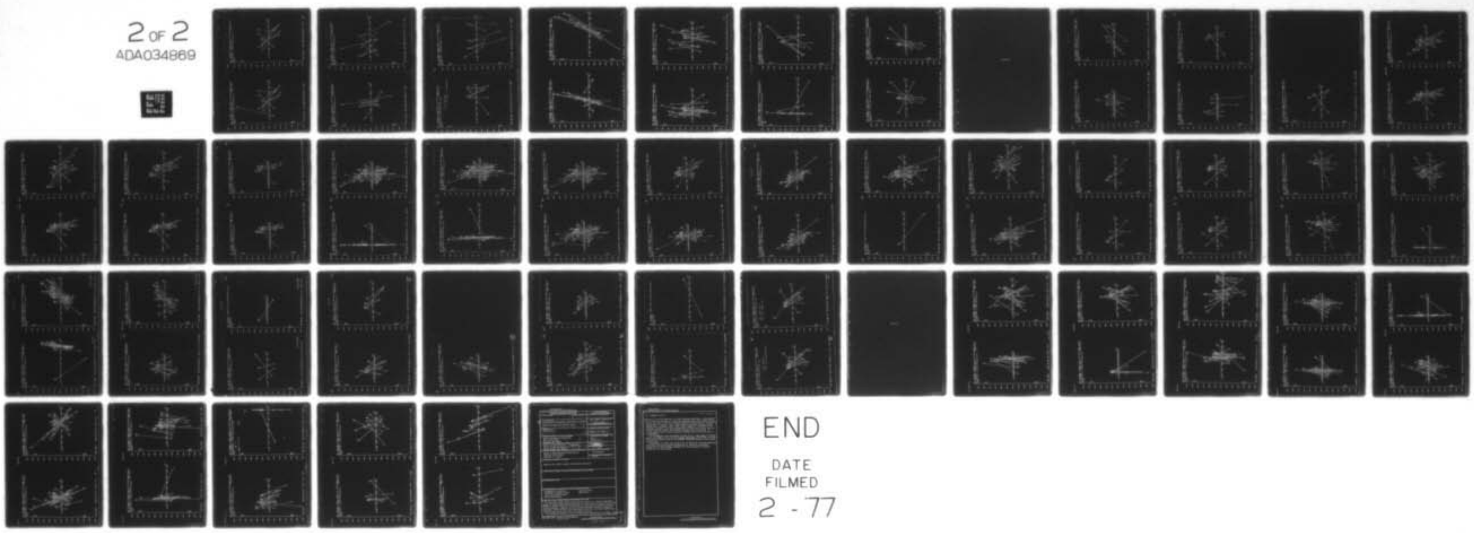


DAY 299-303 1974 DSDP SITE 354 HT: +17 M

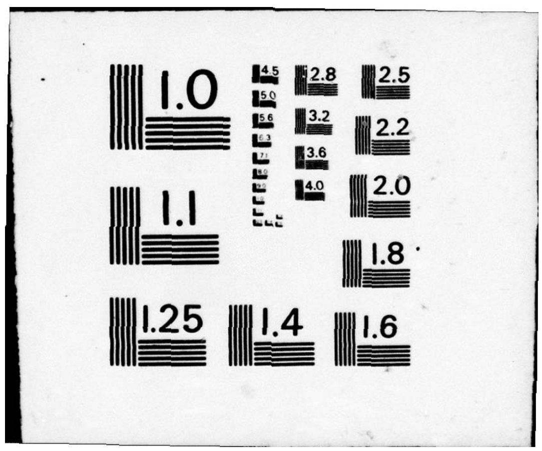
20

AD-A034 869 HAWAII INST OF GEOPHYSICS HONOLULU F/G 8/5
GEOID HEIGHTS AND GEODETIC POSITIONS OF PACIFIC HARBORS AND DEE--ETC(U)
NOV 76 E BERG N00014-75-C-0209
UNCLASSIFIED NL

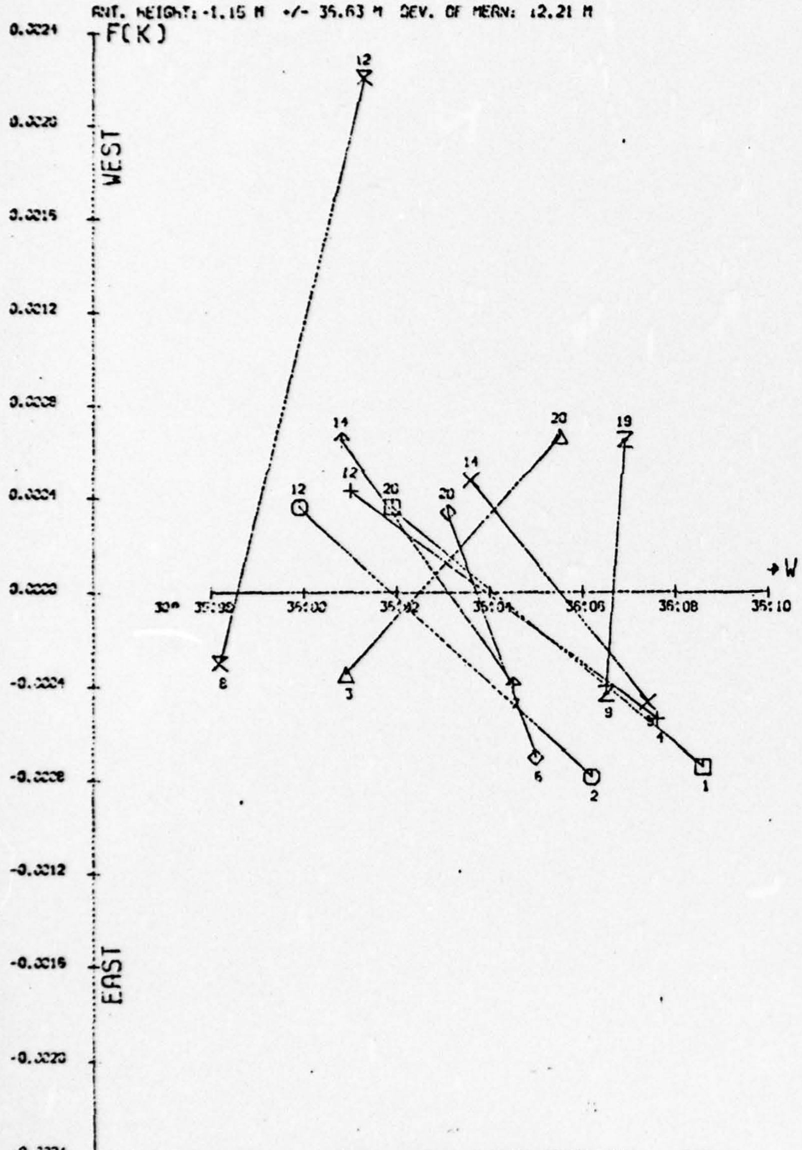
2 OF 2
ADA034869



END
DATE
FILMED
2 - 77

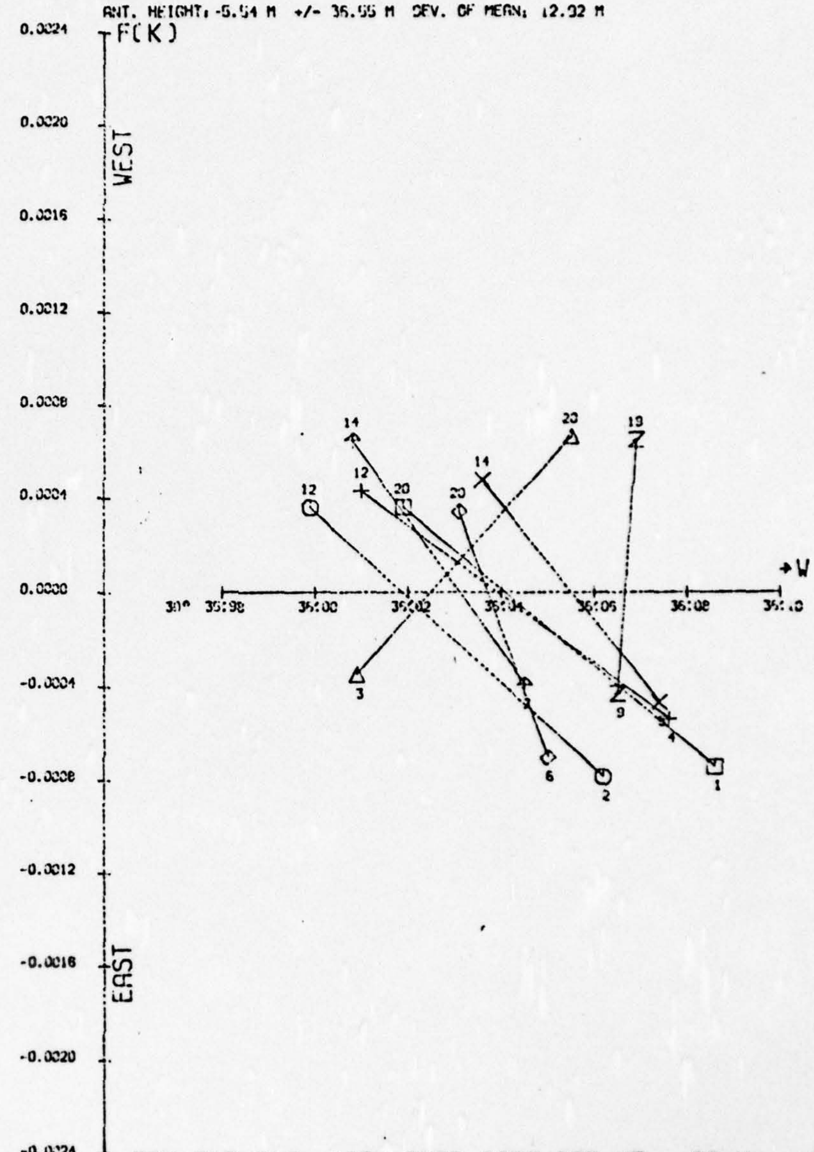

1.0
4.5
5.0
5.6
6.3
7.1
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

LAT.: -15° 42:5042 +/- 0:0321 (59.50 M) DEV. OF MEAN: 0:0076 (14.03 M)
LONG.. 30° 36:0333 +/- 0:0230 (41.10 M) 0:0077 (13.70 M)
ANT. HEIGHT: -1.15 M +/- 35.63 M DEV. OF MEAN: 12.21 M



DAY 313-315: 1974 DSDP SITE 355 HT: +22 M

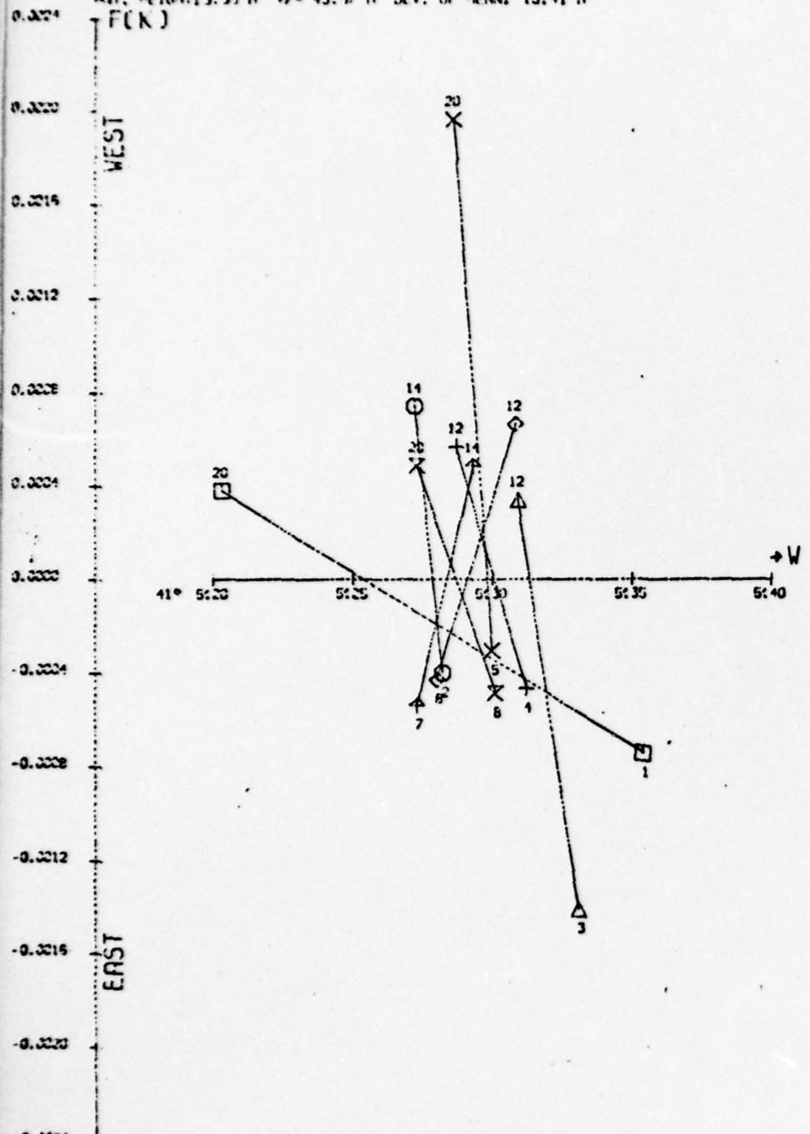
LAT.: -15° 42:5054 +/- 0:0332 (61.55 M) DEV. OF MEAN: 0:0083 (15.39 M)
LONG.. 30° 36:0392 +/- 0:0156 (27.82 M) 0:0055 (9.84 M)
ANT. HEIGHT: -5.54 M +/- 36.55 M DEV. OF MEAN: 12.92 M



DAY 313-315 1974 DSDP SITE 355 HT: +22 M 2σ

1 Sept 74

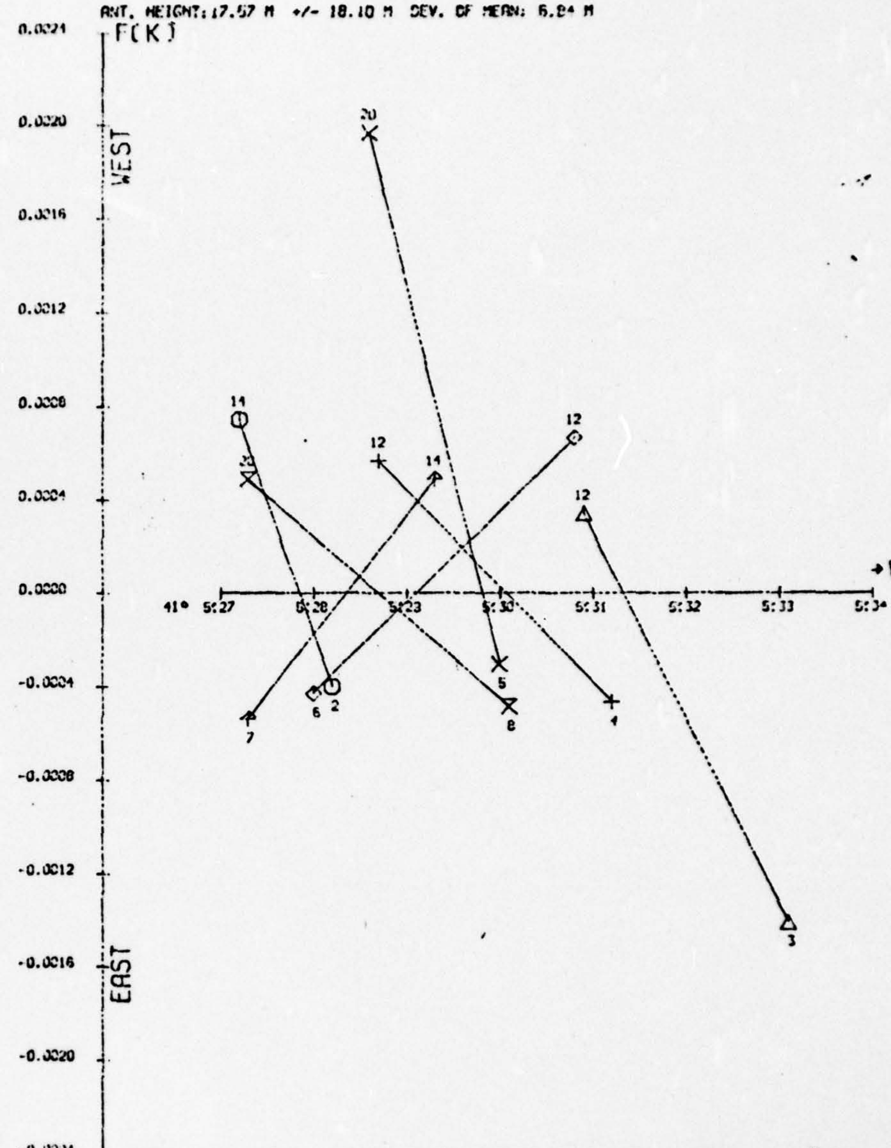
LAT.. -28° 17:2203 +/- 0:0555 (108.35 M) DEV. OF MEAN: 0:0146 (27.09 M)
LONG.. 41° 5:2893 +/- 0:0176 (28.73 M) 0:0062 (10.16 M)
ANT. HEIGHT: 3.35 M +/- 43.57 M DEV. OF MEAN: 15.41 M



DAY 321-323 1974 DSDP SITE 356 HT: +22 M

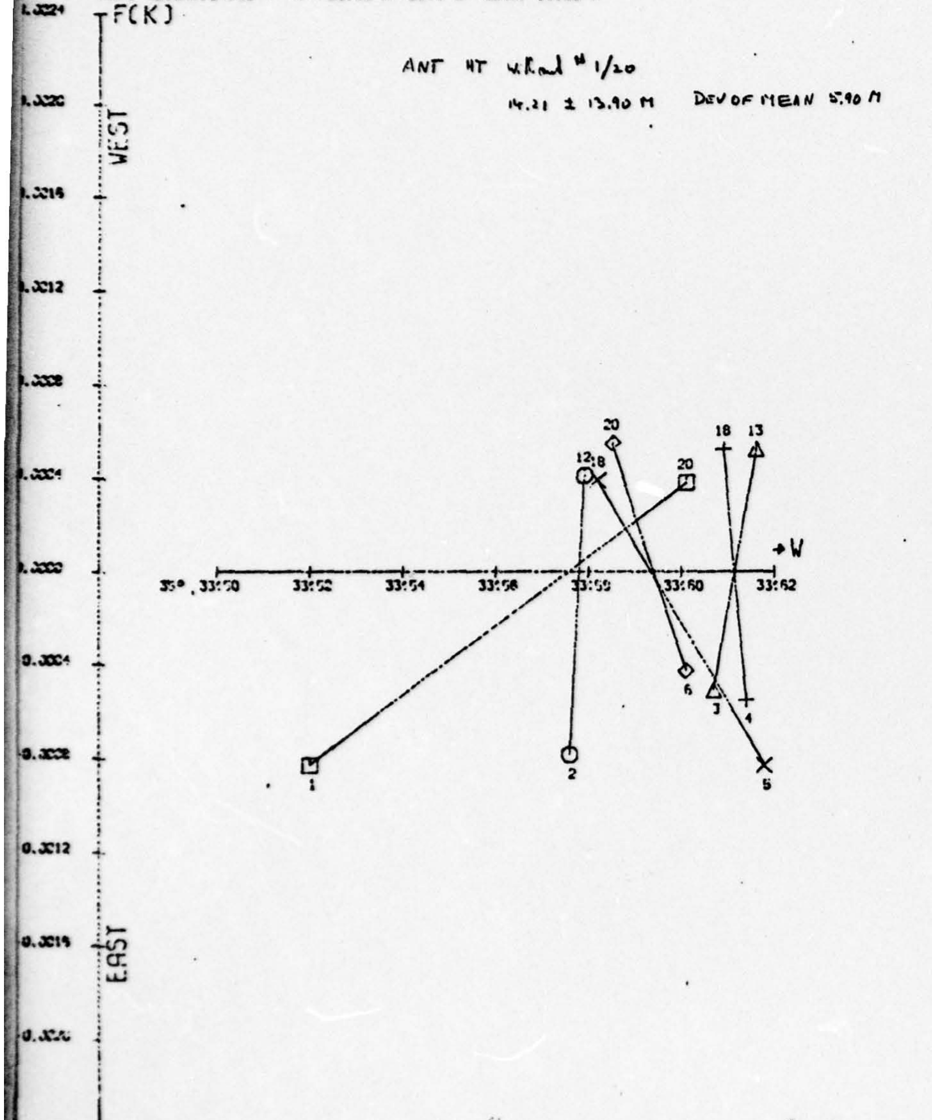
1 Sept 74

LAT.: -28° 17:2151 +/- 0:0605 (112.11 M) DEV. OF MEAN: 0:0162 (23.95 M)
LONG.. 41° 5:2331 +/- 0:0118 (19.28 M) 0:0045 (7.23 M)
ANT. HEIGHT: 17.57 M +/- 18.10 M DEV. OF MEAN: 6.24 M



DAY 321-323 1974 DSDP SITE 356 HT: +22 M 2σ

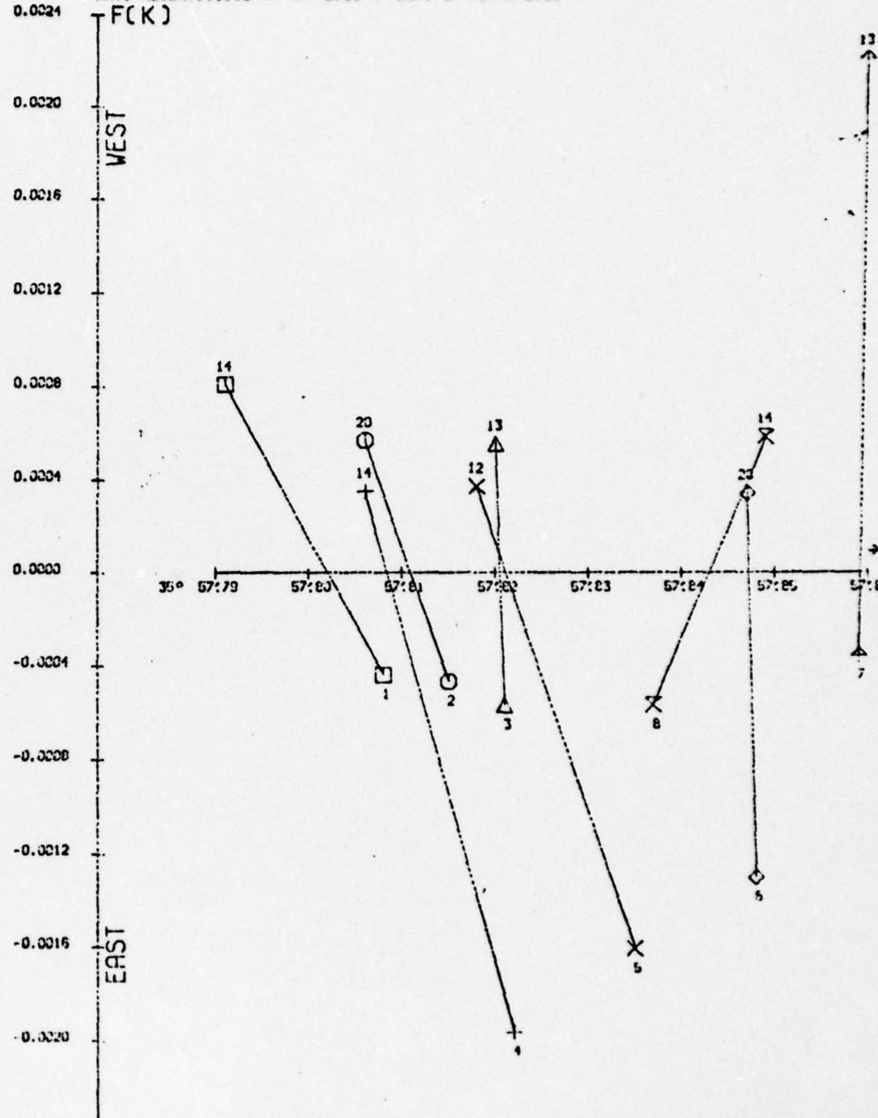
LAT.: -30° 0:2529 +/- 0:0288 (53.44 M) DEV. OF MEAN: 0:0083 (15.43 M)
LONG.. 35° 33:5940 +/- 0:0155 (24.91 M) 0:0053 (10.17 M)
ANT. HEIGHT:24.98 M +/- 28.90 M DEV. OF MEAN: 11.80 M



DAY 328-330 1974 DSDP SITE 357 HT: +21 M (2σ)

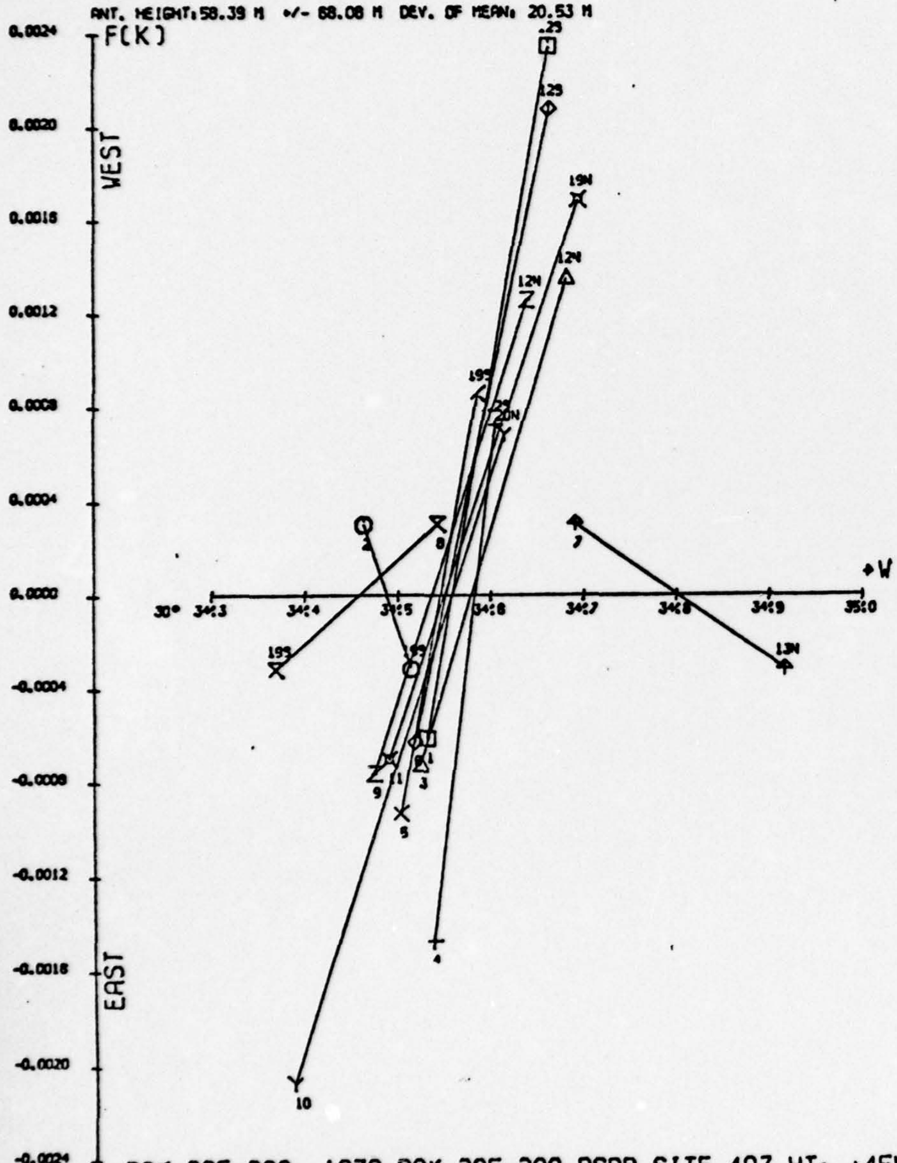
1 Sep 76

LAT.: -37° 39:3069 +/- 0:0183 (34.97 M) DEV. OF MEAN: 0:0047 (8.74 M)
LONG.. 35° 57:8265 +/- 0:0207 (30.35 M) 0:0073 (10.73 M)
ANT. HEIGHT:11.18 M +/- 5.93 M DEV. OF MEAN: 2.10 M



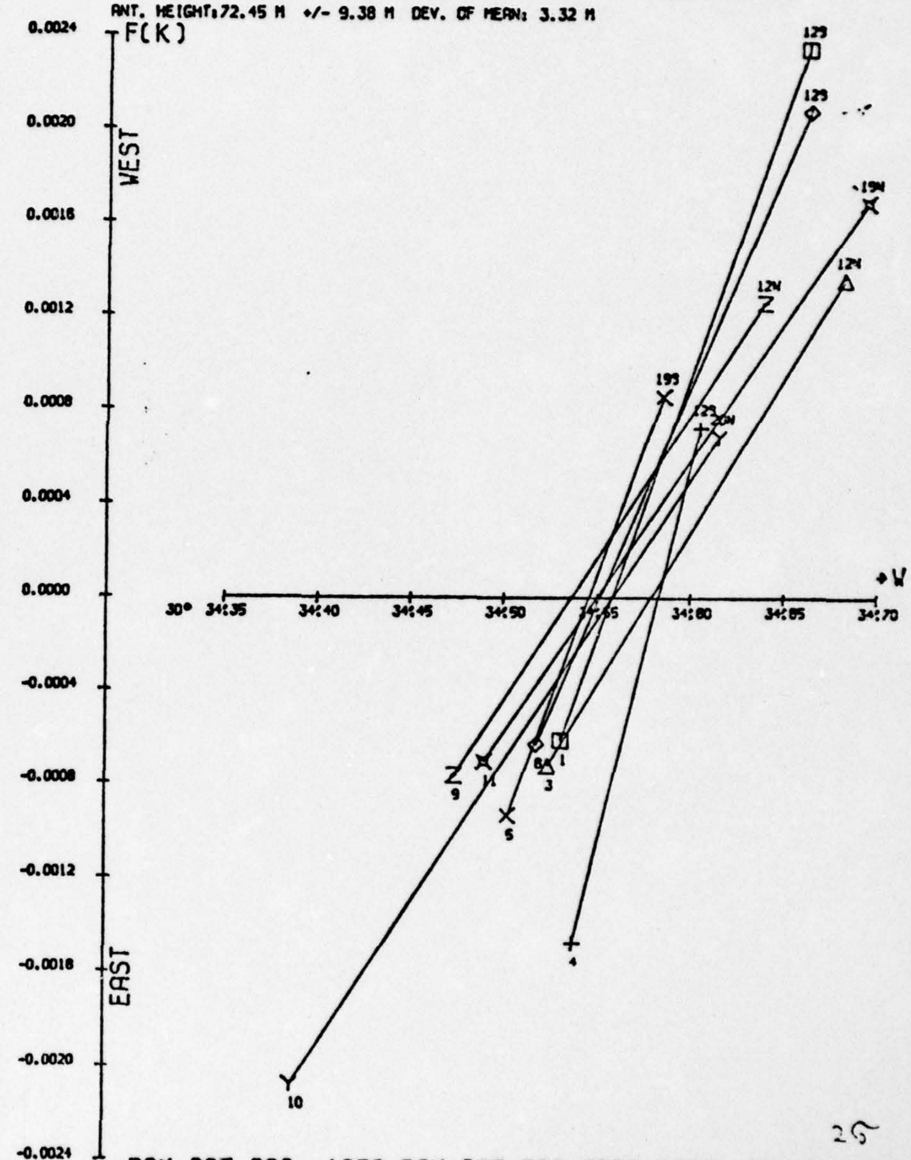
DAY 335-336 1974 DSDP SITE 358 HT: +14 M (2σ)

LAT.: 63° 58:3037 +/- 0:0301 (55.87 M) DEV. OF MEAN: 0:0084 (11.91 M)
LONG.: 30° 34:5844 +/- 0:0868 (70.65 M) 0:0262 (21.30 M)
ANT. HEIGHT: 58.39 M +/- 68.08 M DEV. OF MEAN: 20.53 M



DAY 205-209 1976 DAY 205-209 DSDP SITE 407 HT: +45M

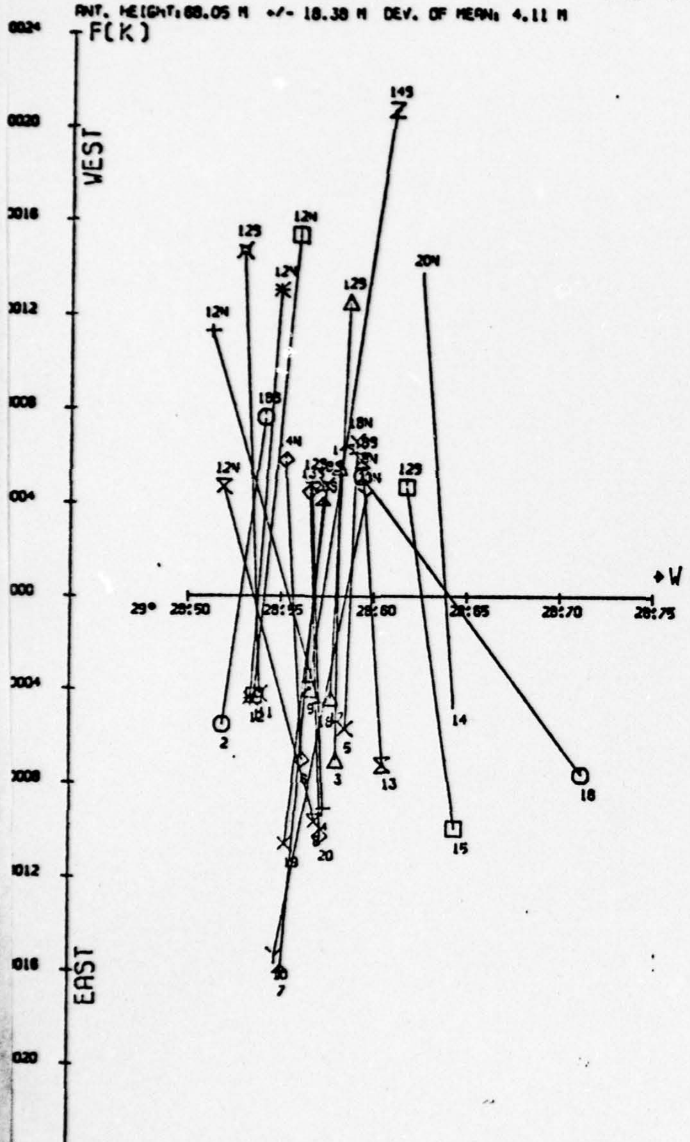
LAT.: 63° 58:3086 +/- 0:0128 (23.80 M) DEV. OF MEAN: 0:0032 (5.95 M)
LONG.: 30° 34:5577 +/- 0:0160 (12.99 M) 0:0058 (4.59 M)
ANT. HEIGHT: 72.45 M +/- 9.38 M DEV. OF MEAN: 3.32 M



DAY 205-209 1976 DAY 205-209 DSDP SITE 407 HT: +45M

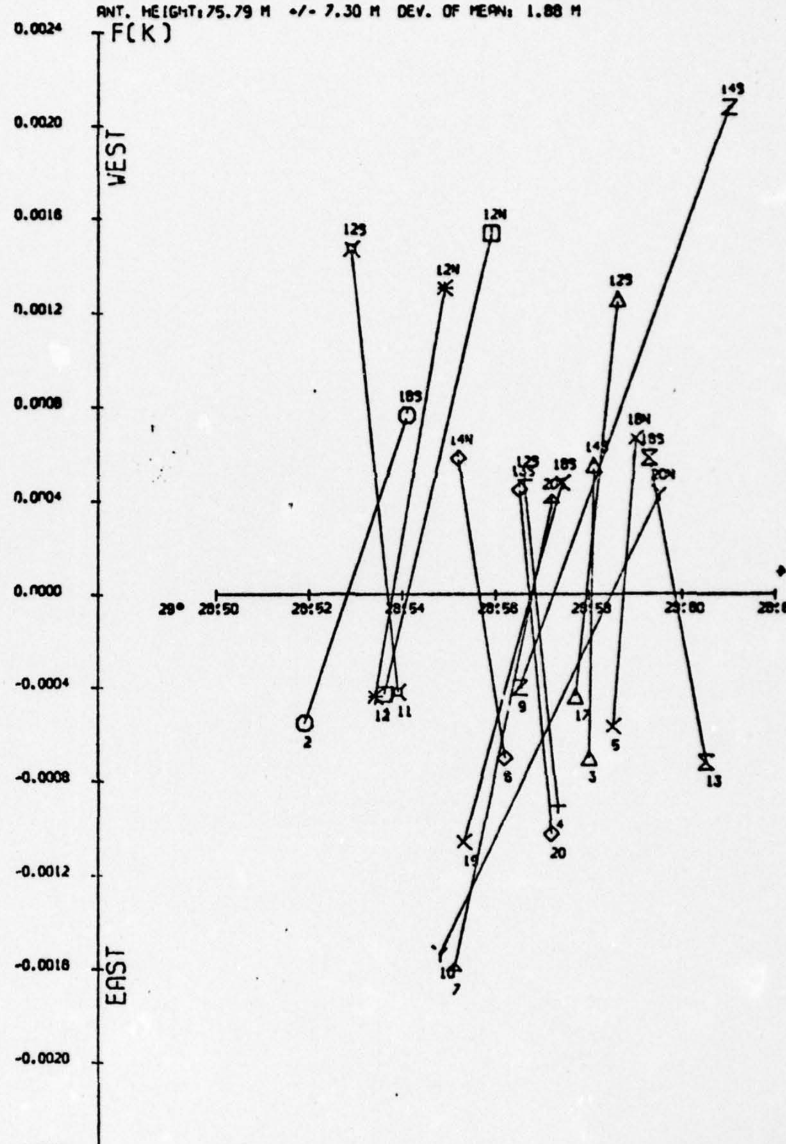
25

LAT.: 45° 30:5151 +/- 0:0230 (42.59 M) DEV. OF MEAN: 0:0038 (8.73 M)
LONG.: 29° 28:5727 +/- 0:0329 (42.71 M) 0:0074 (9.55 M)
ANT. HEIGHT: 88.05 M +/- 18.38 M DEV. OF MEAN: 4.11 M



DAY 227-231 1976 DAY 227-231 DSDP SITE 410 HT: +72M

LAT.: 45° 30:5151 +/- 0:0250 (48.32 M) DEV. OF MEAN: 0:0046 (8.46 M)
LONG.: 29° 28:5844 +/- 0:0209 (27.10 M) 0:0054 (7.00 M)
ANT. HEIGHT: 75.79 M +/- 7.30 M DEV. OF MEAN: 1.88 M

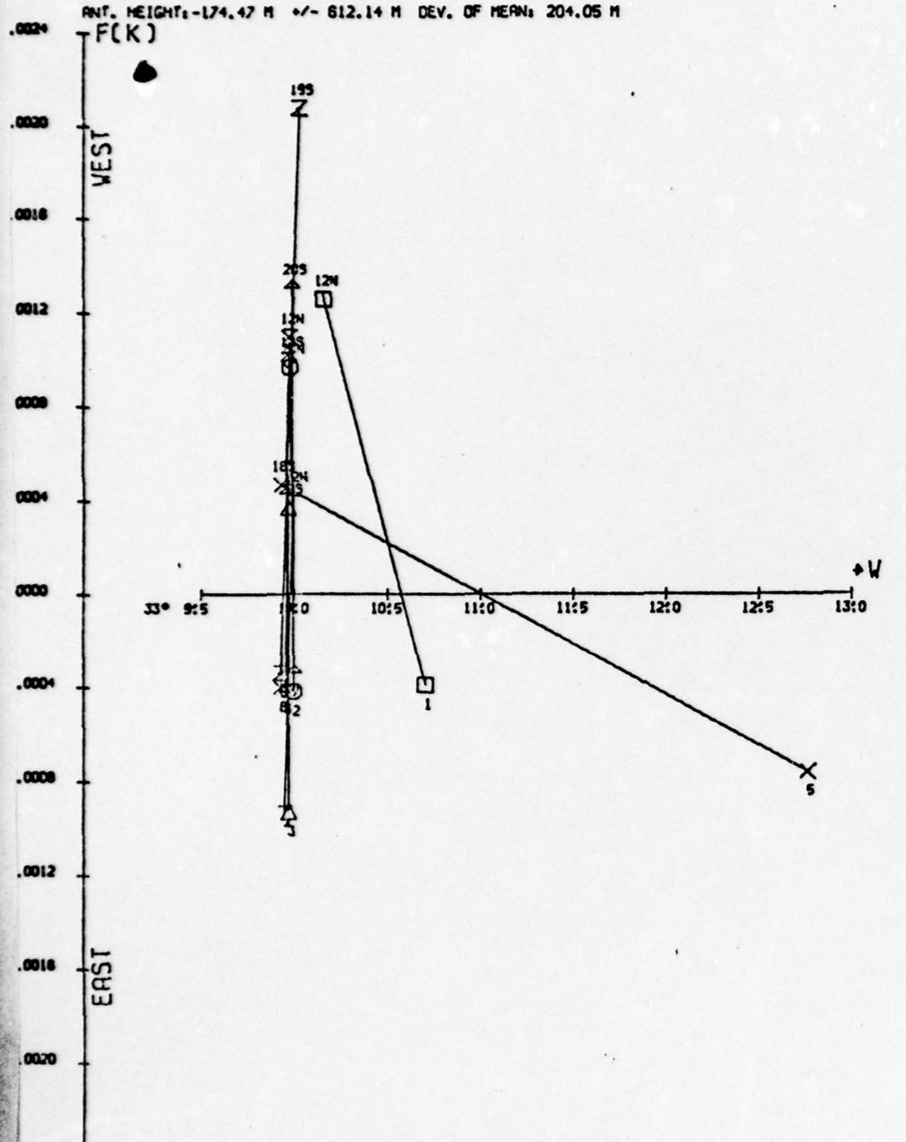


DAY 227-231 1976 DAY 227-231 DSDP SITE 410 HT: +72M

26

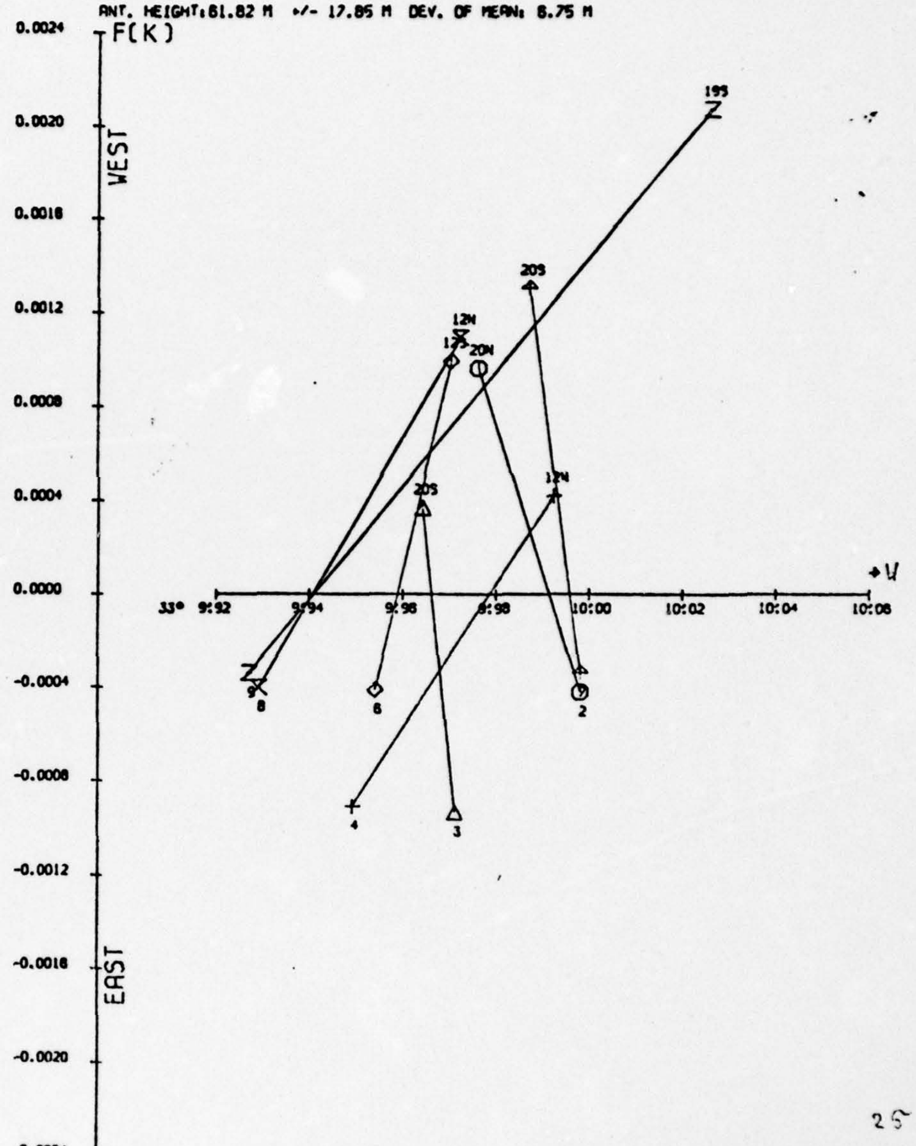
HOUSTON INSTRUMENT BELLAIRE, TEXAS CHART NO. PC-000 PRINTED IN U.S.A.

LAT.: 38° 36:0850 +/- 10:0805 (18681.14 M) DEV. OF MEAN: 2:3760 (4403.18 M)
LONG.: 33° 10:1494 +/- 0:3782 (582.63 M) 0:1261 (187.54 M)
ANT. HEIGHT: -174.47 M +/- 612.14 M DEV. OF MEAN: 204.05 M



DAY 237-239 1976 DAY 237-239 DSDP SITE 412A HT: 52M

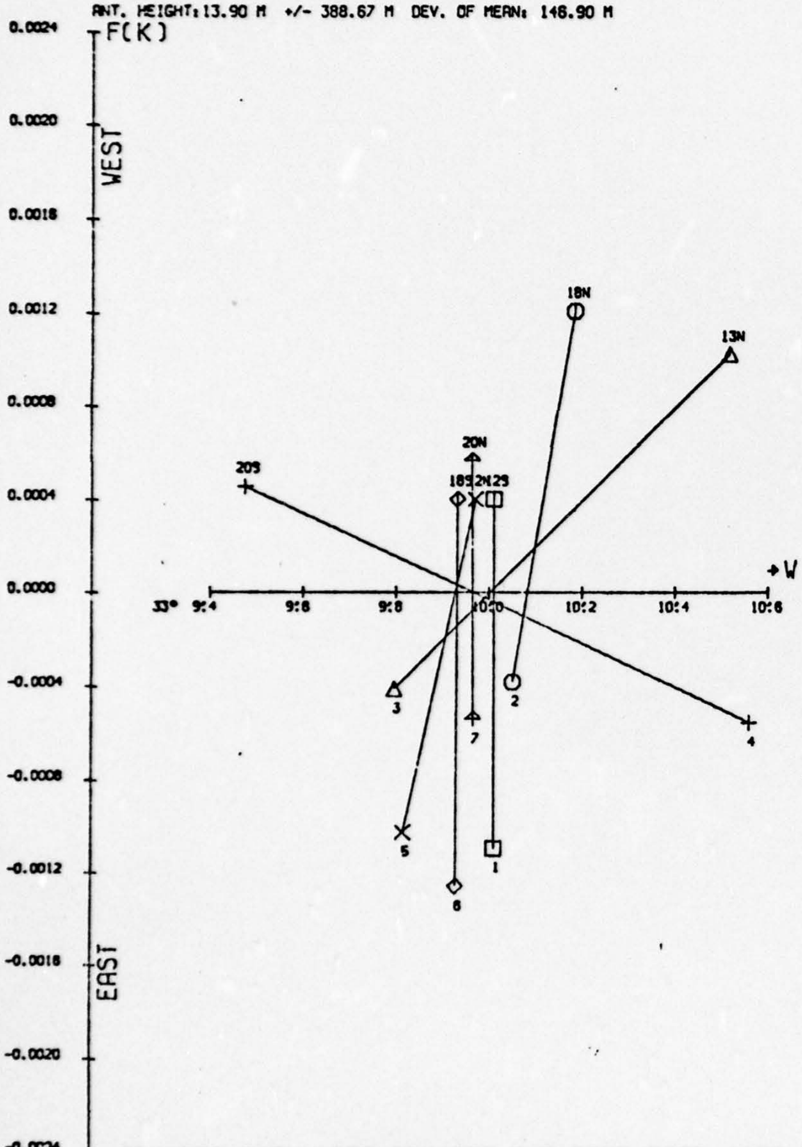
LAT.: 38° 33:7268 +/- 0:0677 (125.46 M) DEV. OF MEAN: 0:0181 (33.53 M)
LONG.: 33° 9:9670 +/- 0:0223 (33.23 M) 0:0084 (12.56 M)
ANT. HEIGHT: 61.82 M +/- 17.85 M DEV. OF MEAN: 8.75 M



DAY 237-239 1976 DAY 237-239 DSDP SITE 412A HT: 52M

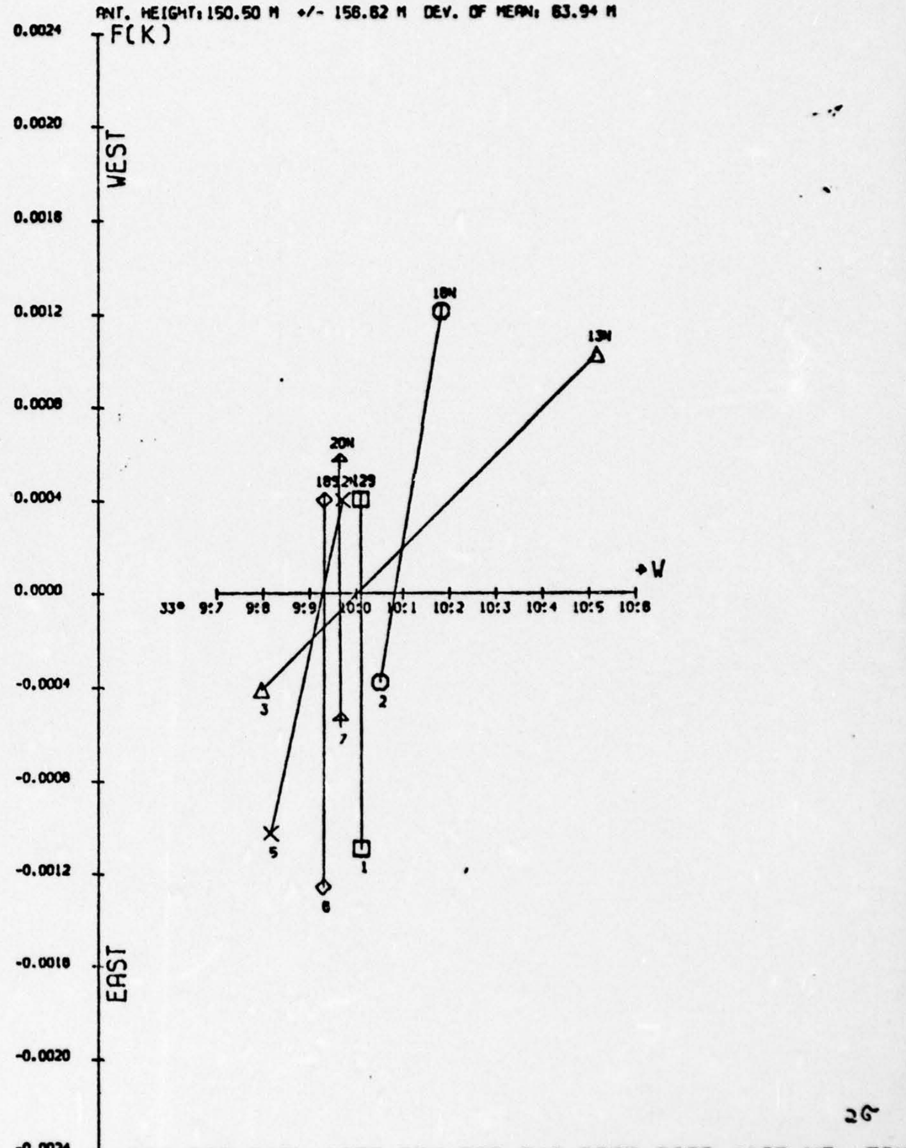
25

LAT.: 36° 33:8149 +/- 0:1283 (237.73 M) DEV. OF MEAN: 0:0343 (83.54 M)
LONG.: 33° 9:9835 +/- 0:0539 (80.22 M) 0:0204 (30.32 M)
ANT. HEIGHT: 13.90 M +/- 388.67 M DEV. OF MEAN: 146.90 M



DAY 239-240 1976 DAY 239-240 DSDP SITE 412B HT: 58M

LAT.: 36° 33:8347 +/- 0:1280 (237.18 M) DEV. OF MEAN: 0:0369 (68.47 M)
LONG.: 33° 9:9864 +/- 0:0585 (87.01 M) 0:0239 (35.52 M)
ANT. HEIGHT: 150.50 M +/- 158.82 M DEV. OF MEAN: 83.94 M



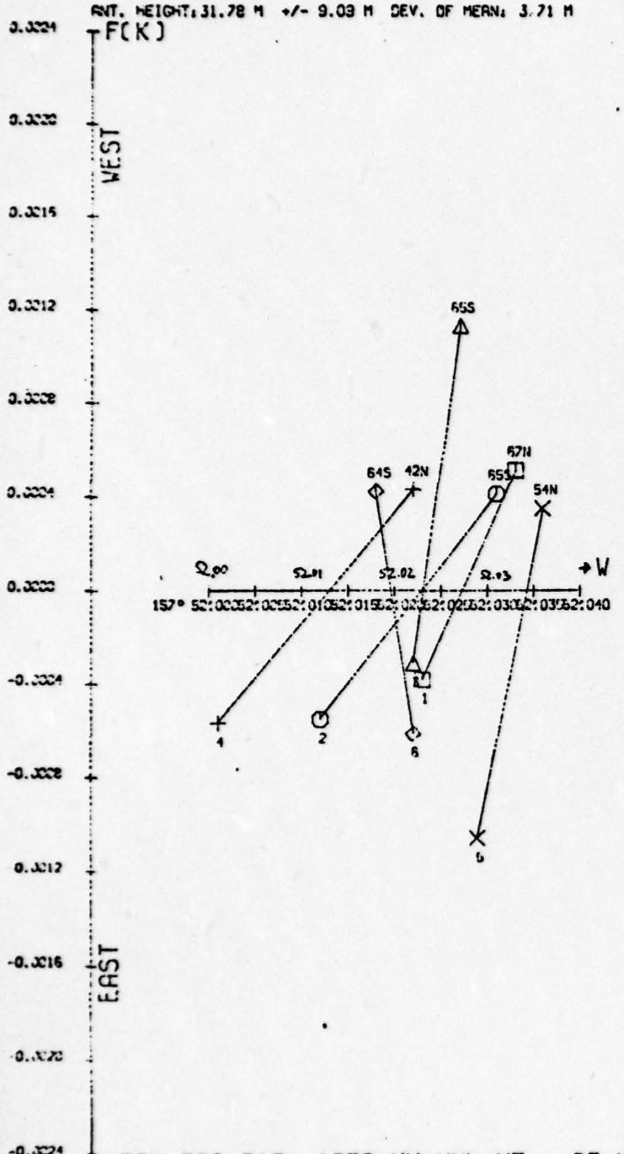
DAY 239-240 1976 DAY 239-240 DSDP SITE 412B HT: 58M

2G

Group III

137

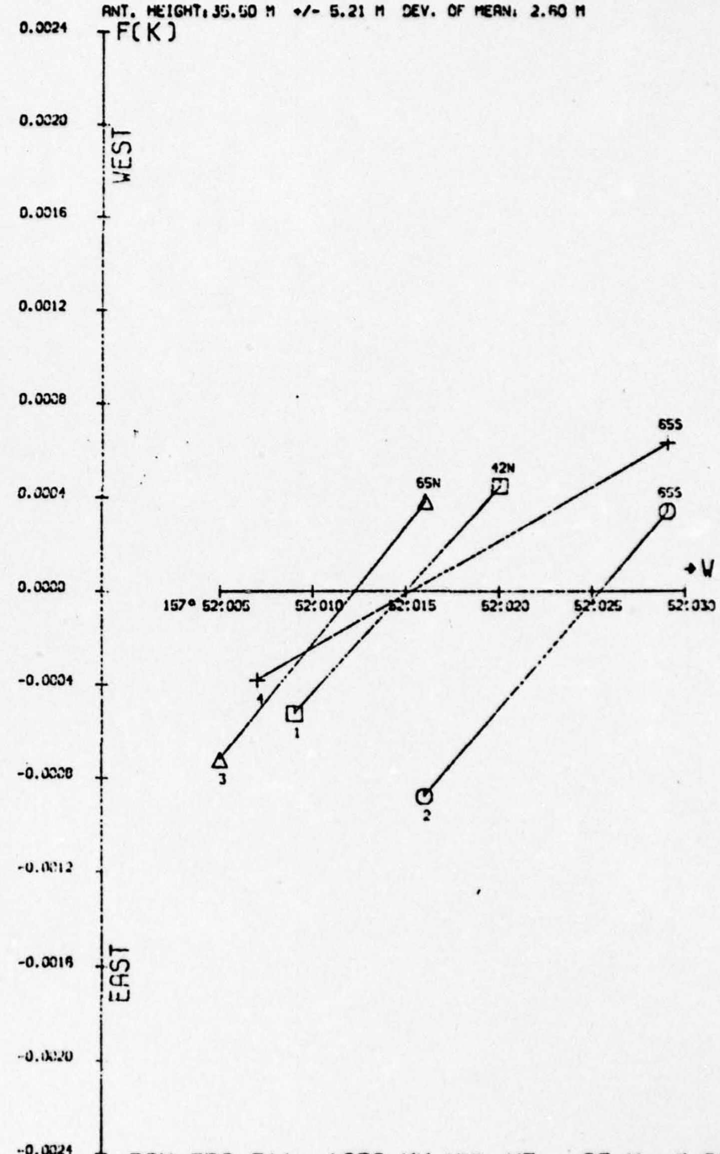
LAT.: 21° 18:8086 +/- 0:0229 (42.35 M) DEV. OF MEAN: 0:0066 (12.22 M)
LONG. 157° 52:0233 +/- 0:0072 (12.38 M) 0:0029 (5.06 M)
ANT. HEIGHT: 31.78 M +/- 9.03 M DEV. OF MEAN: 3.71 M



DAY 306-313 1972 KK HNL HT: +23 M # 25 DC>5 (3σ)

138

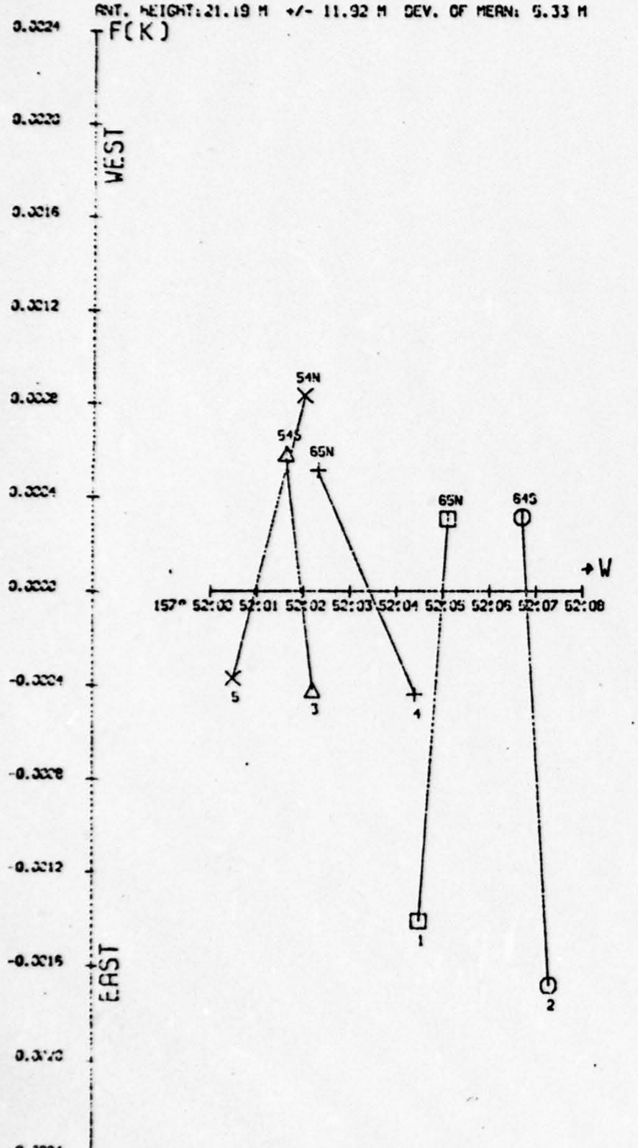
LAT.: 21° 18:8401 +/- 0:0289 (53.47 M) DEV. OF MEAN: 0:0102 (18.91 M)
LONG.. 157° 52:0169 +/- 0:0059 (9.98 M) 0:0023 (4.33 M)
ANT. HEIGHT: 35.50 M +/- 5.21 M DEV. OF MEAN: 2.60 M



DAY 309-311 1972 KK HNL HT: +23 M # 26 D.C>5 (3σ)

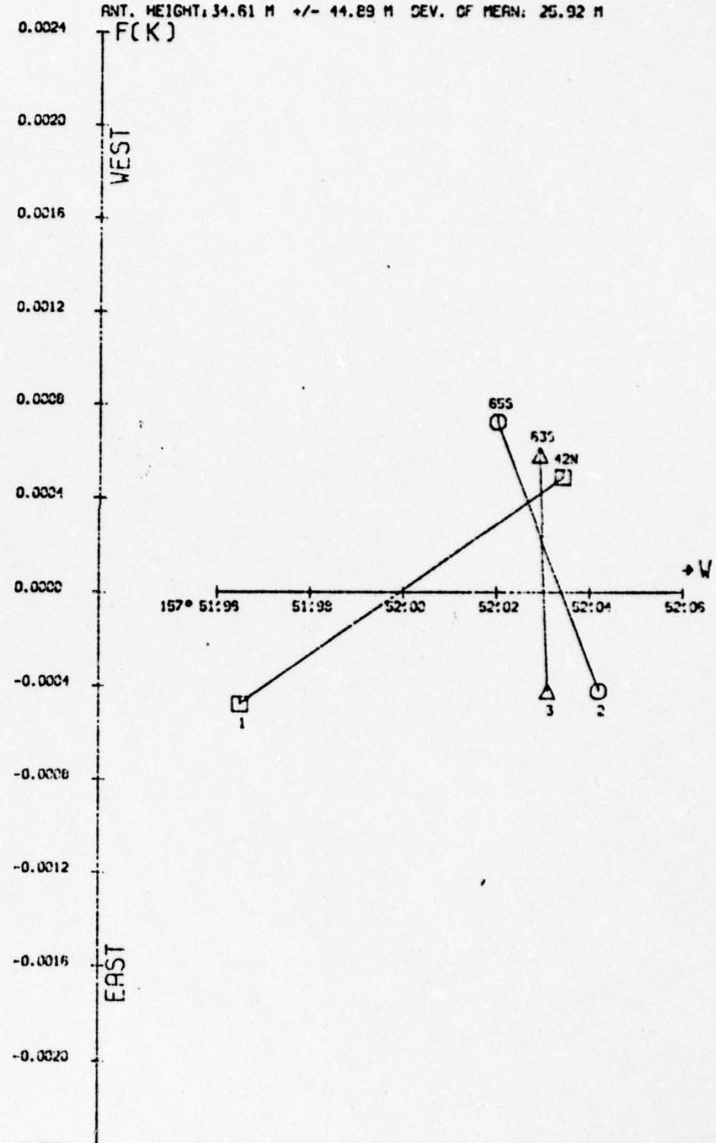
9

LAT.: 21° 18:8162 +/- 0:0305 (56.45 M) DEV. OF MEAN: 0:0096 (17.85 M)
LONG.. 157° 52:0362 +/- 0:0234 (40.34 M) 0:0104 (18.04 M)
ANT. HEIGHT: 21.19 M +/- 11.92 M DEV. OF MEAN: 5.33 M



DAY 204-207 1973 KK HNL HT: +24 M # 38 D.C.>5 (3σ)

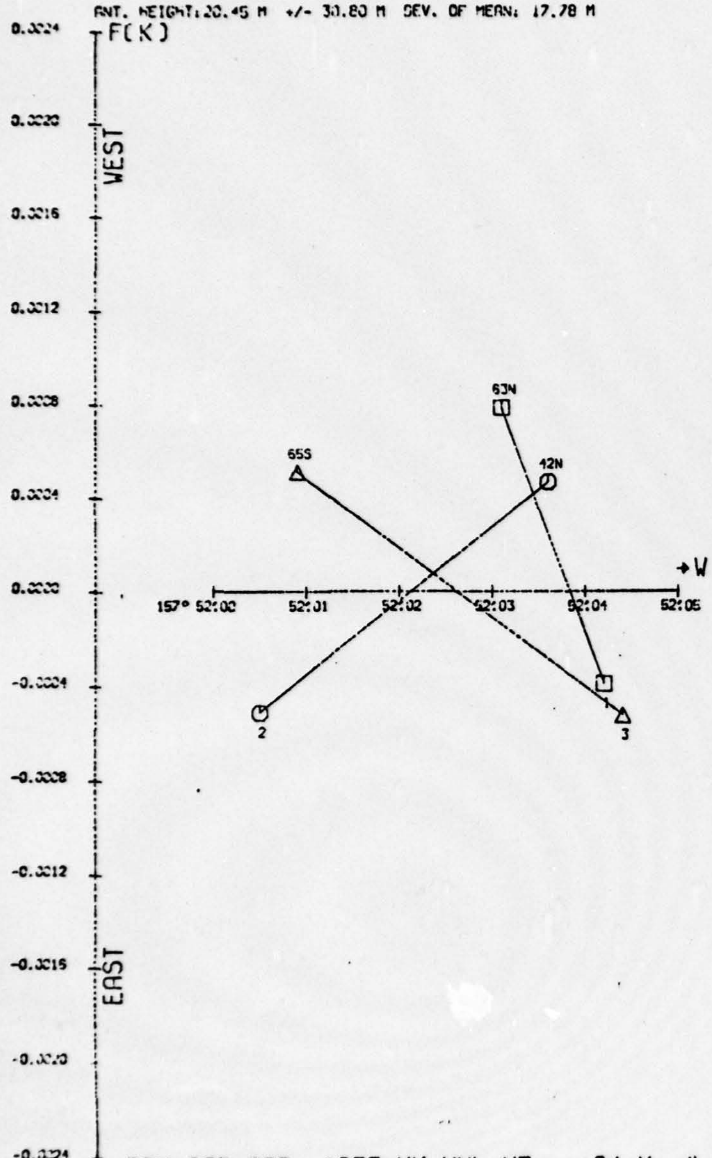
LAT.: 21° 18:8147 +/- 0:0223 (42.48 M) DEV. OF MEAN: 0:0094 (17.34 M)
LONG.. 157° 52:0210 +/- 0:0191 (32.97 M) 0:0110 (19.03 M)
ANT. HEIGHT: 34.61 M +/- 44.89 M DEV. OF MEAN: 25.92 M



DAY 251-252 1973 KK HNL HT: +19 M # 39A D.C>5 (3σ)

141

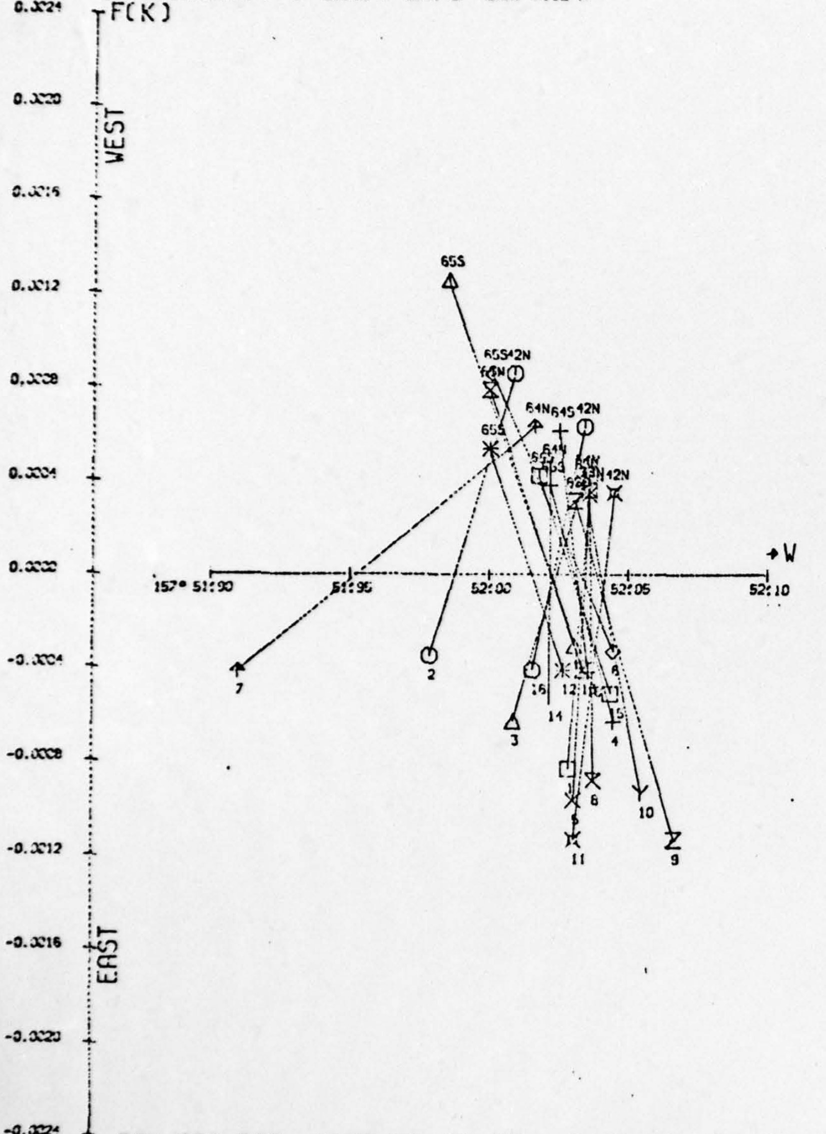
LAT.: 21° 18:8098 +/- 0:0204 (37.89 M) DEV. OF MEAN: 0:0083 (15.47 M)
LONG.. 157° 52:0285 +/- 0:0088 (15.21 M) 0:0051 (8.78 M)
ANT. HEIGHT: 20.45 M +/- 30.80 M DEV. OF MEAN: 17.78 M



DAY 252-253 1973 KK HNL HT: + 24 M # 39B D.C.>5(3σ)

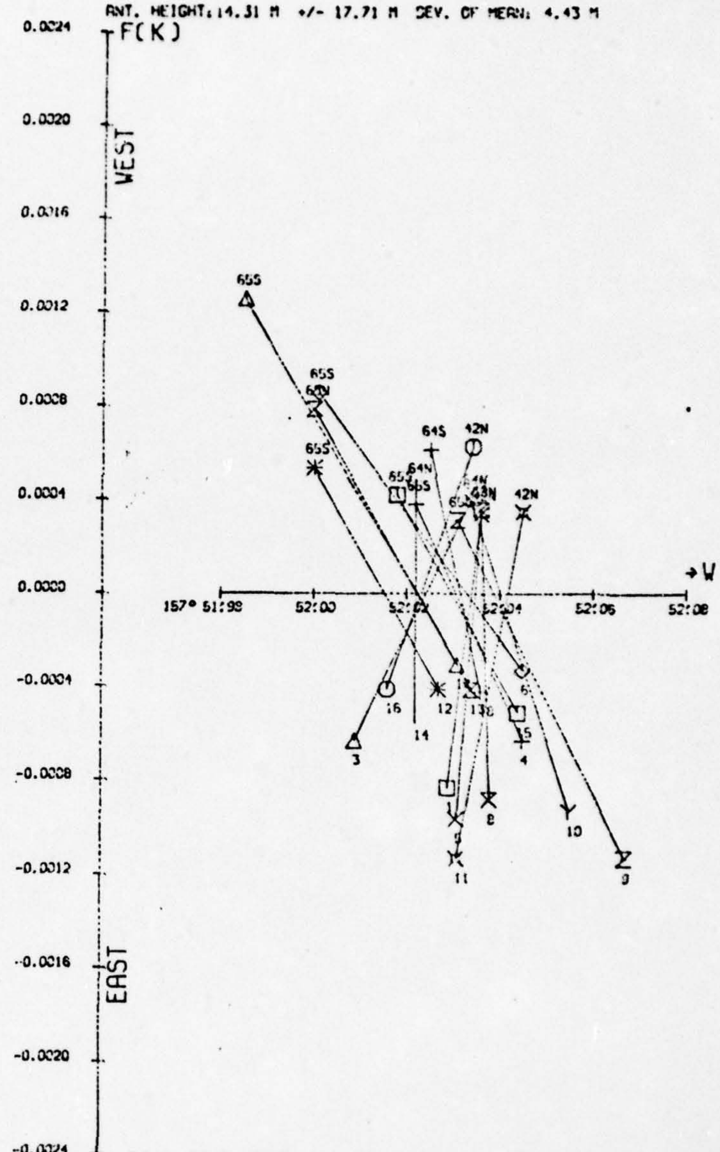
23 24

LAT.: 21° 18:8020 +/- 0:0446 (82.67 M) DEV. OF MEAN: 0:0074 (13.78 M)
LONG.. 157° 52:0233 +/- 0:0215 (37.19 M) 0:0051 (8.77 M)
ANT. HEIGHT: 21.89 M +/- 30.19 M DEV. OF MEAN: 7.12 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.74

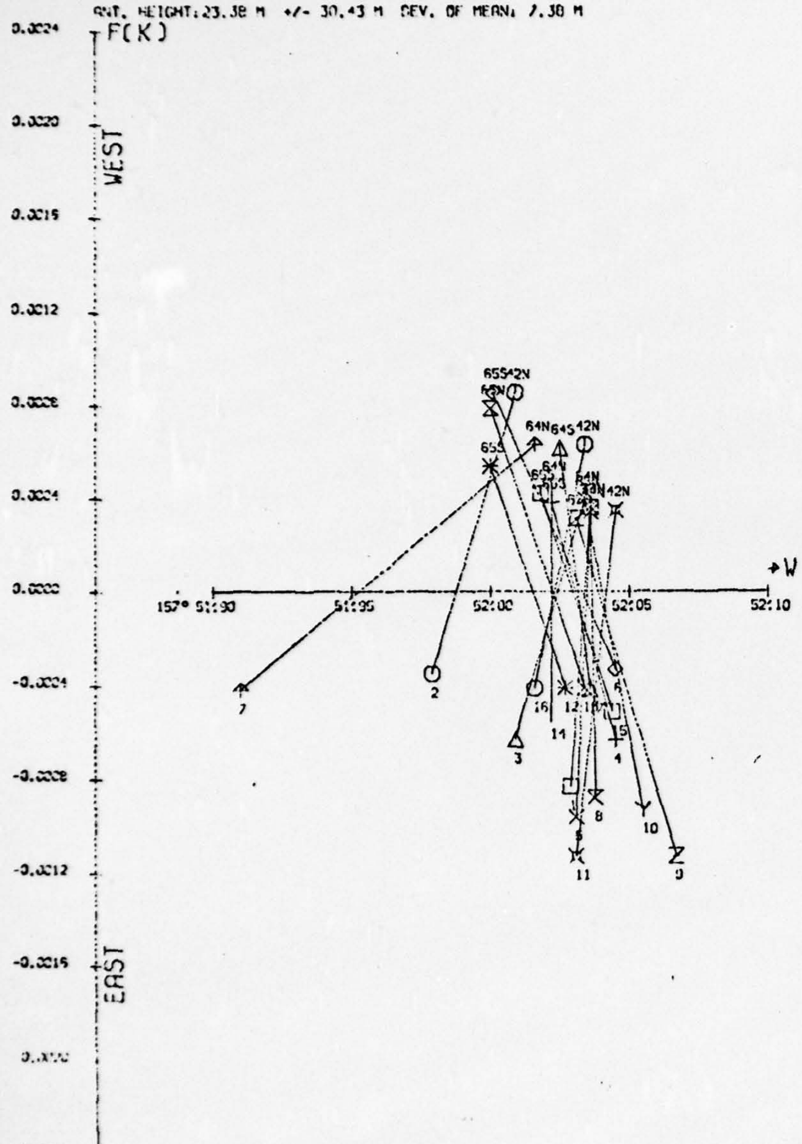
LAT.: 21° 18:7964 +/- 0:0217 (40.17 M) DEV. OF MEAN: 0:0038 (7.10 M)
LONG.. 157° 52:0239 +/- 0:0077 (13.34 M) 0:0019 (3.33 M)
ANT. HEIGHT: 14.31 M +/- 17.71 M DEV. OF MEAN: 4.43 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 3σ D.C.74

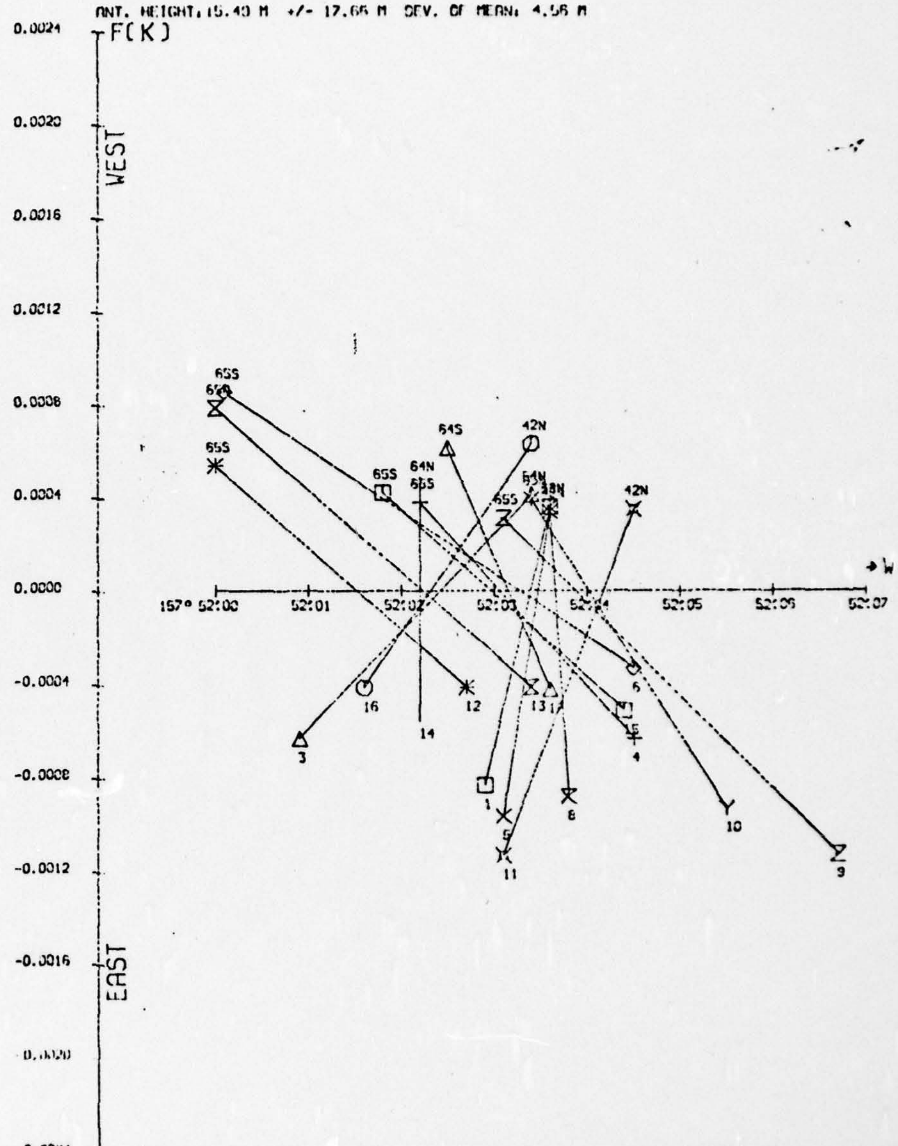
142 143

LAT.: 21° 18:8022 +/- 0:0458 (84.94 M) DEV. OF MEAN: 0:0079 (14.57 M)
LONG.. 157° 52:0233 +/- 0:0222 (38.34 M) 0:0054 (9.30 M)
ANT. HEIGHT:23.38 M +/- 30.43 M DEV. OF MEAN: 7.38 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.>5

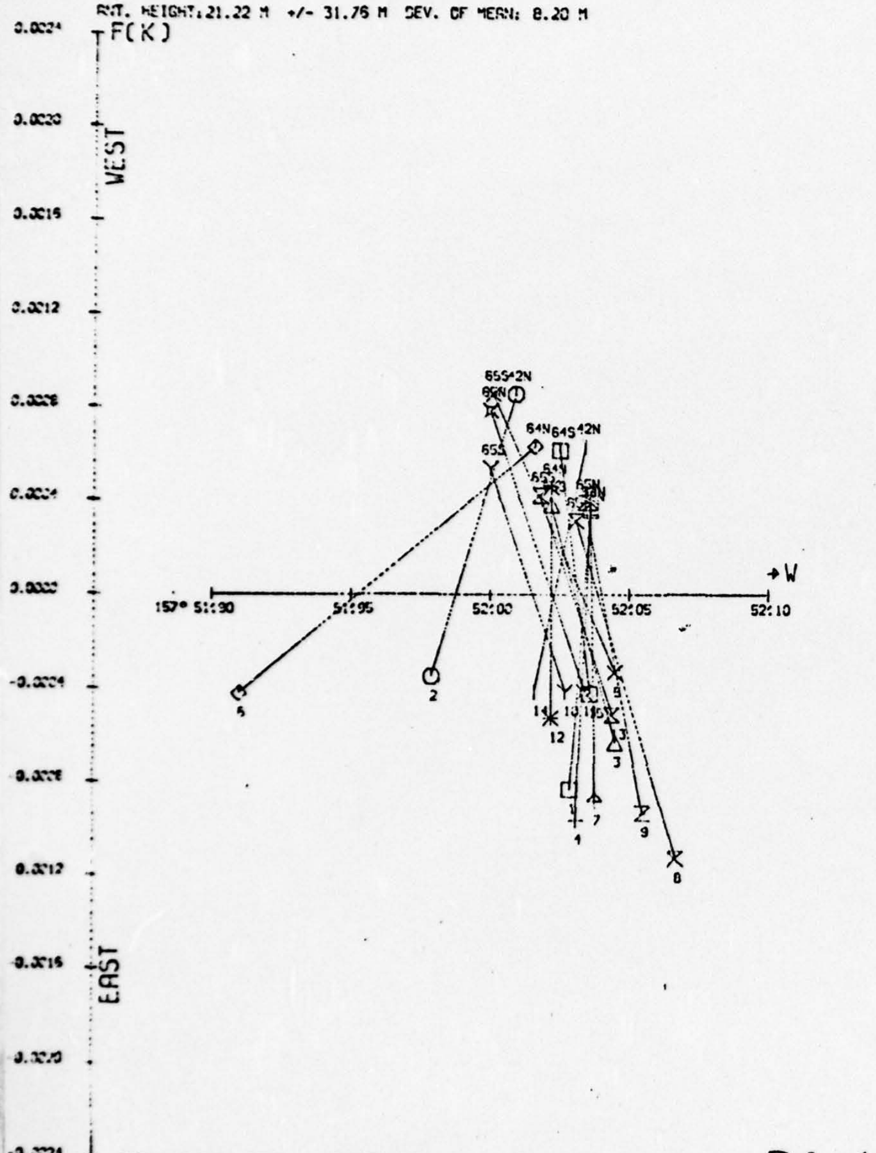
LAT.: 21° 18:7964 +/- 0:0222 (41.15 M) DEV. OF MEAN: 0:0041 (7.51 M)
LONG.. 157° 52:0305 +/- 0:0077 (13.27 M) 0:0020 (3.43 M)
ANT. HEIGHT:15.40 M +/- 17.66 M DEV. OF MEAN: 4.56 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.>5 36

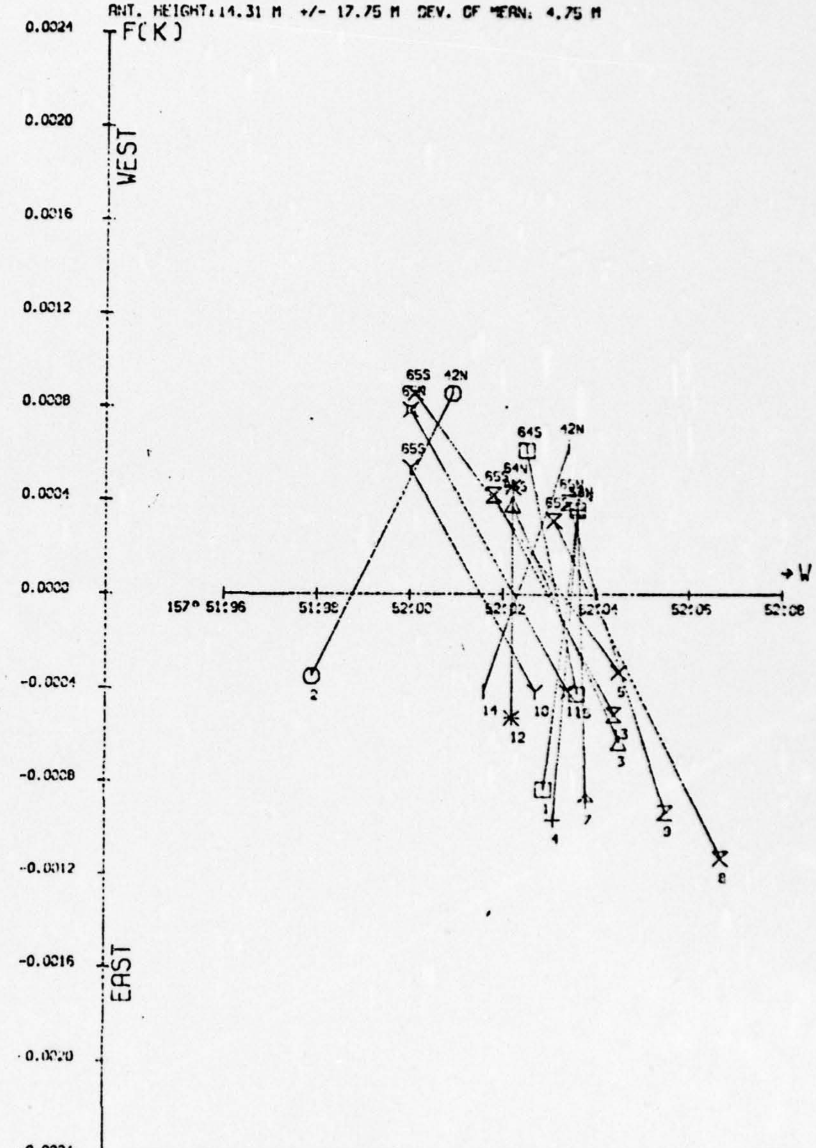
27 28

LAT.: 21° 18:8054 +/- 0:0475 (87.99 M) DEV. OF MEAN: 0:0087 (16.06 M)
LONG.: 157° 52:0221 +/- 0:0232 (40.04 M) 0:0060 (10.34 M)
ANT. HEIGHT: 21.22 M +/- 31.76 M DEV. OF MEAN: 8.20 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.>6

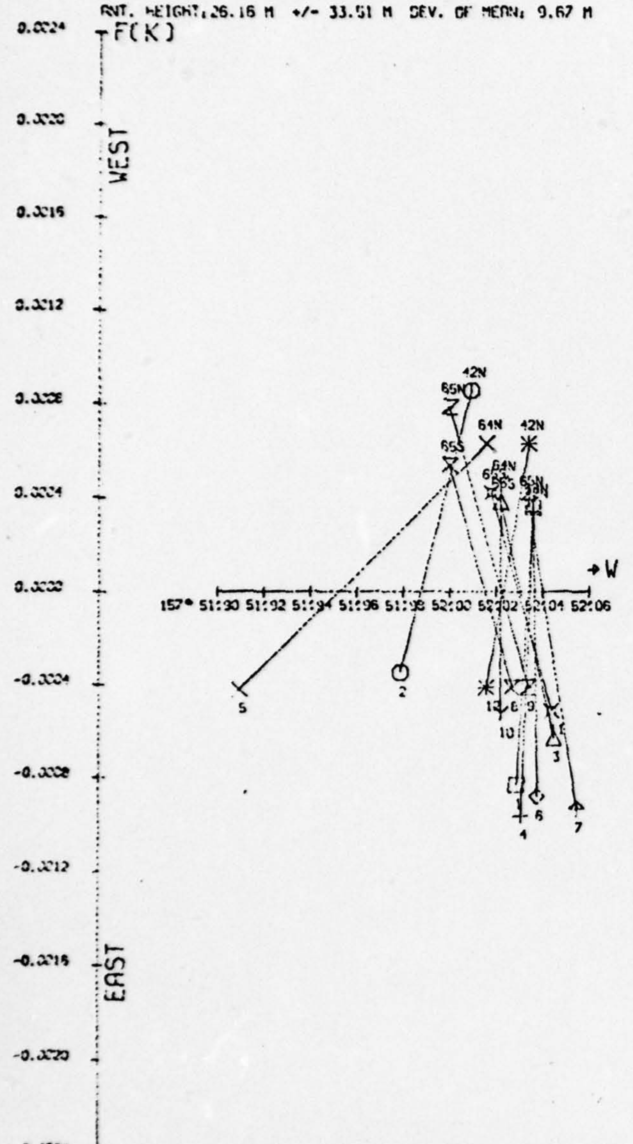
LAT.: 21° 18:7986 +/- 0:0206 (38.21 M) DEV. OF MEAN: 0:0039 (7.22 M)
LONG.: 157° 52:0270 +/- 0:0134 (23.12 M) 0:0036 (6.18 M)
ANT. HEIGHT: 14.31 M +/- 17.75 M DEV. OF MEAN: 4.75 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.>6 3σ

31

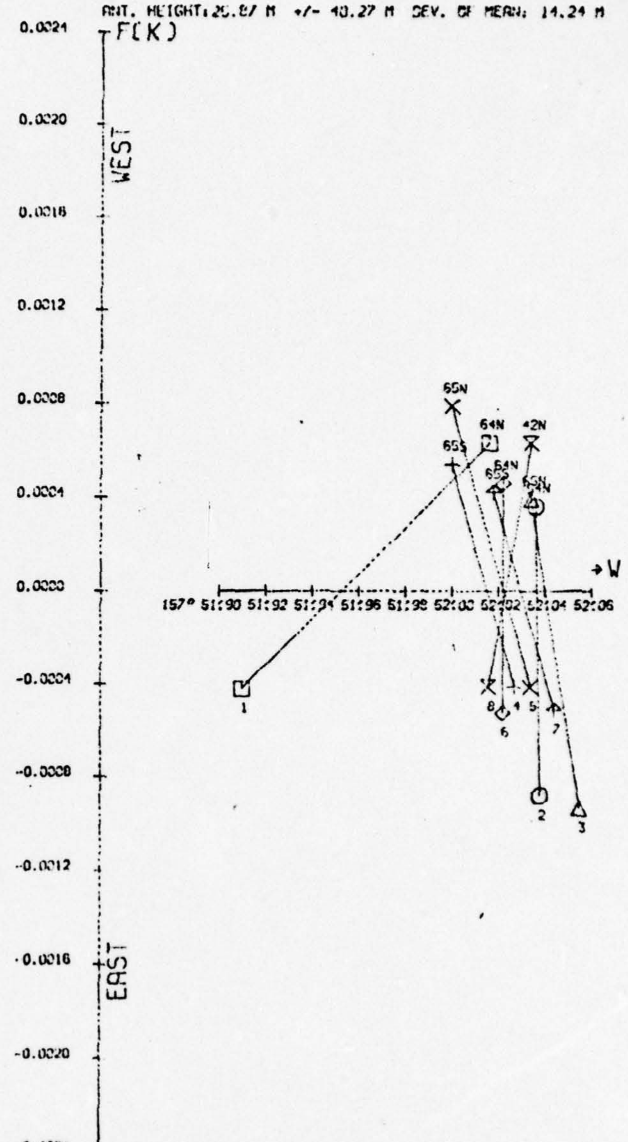
LAT.: 21° 18:8013 +/- 0:0522 (96.75 M) DEV. OF MEAN: 0:0107 (19.75 M)
LONG.: 157° 52:0190 +/- 0:0251 (43.35 M) 0:0072 (12.51 M)
ANT. HEIGHT: 26.16 M +/- 33.51 M DEV. OF MEAN: 9.67 M



DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.>8 (3σ)

33

LAT.: 21° 18:8049 +/- 0:0542 (118.98 M) DEV. OF MEAN: 0:0161 (23.75 M)
LONG.: 157° 52:0177 +/- 0:0276 (47.67 M) 0:0098 (16.86 M)
ANT. HEIGHT: 25.87 M +/- 40.27 M DEV. OF MEAN: 14.24 M

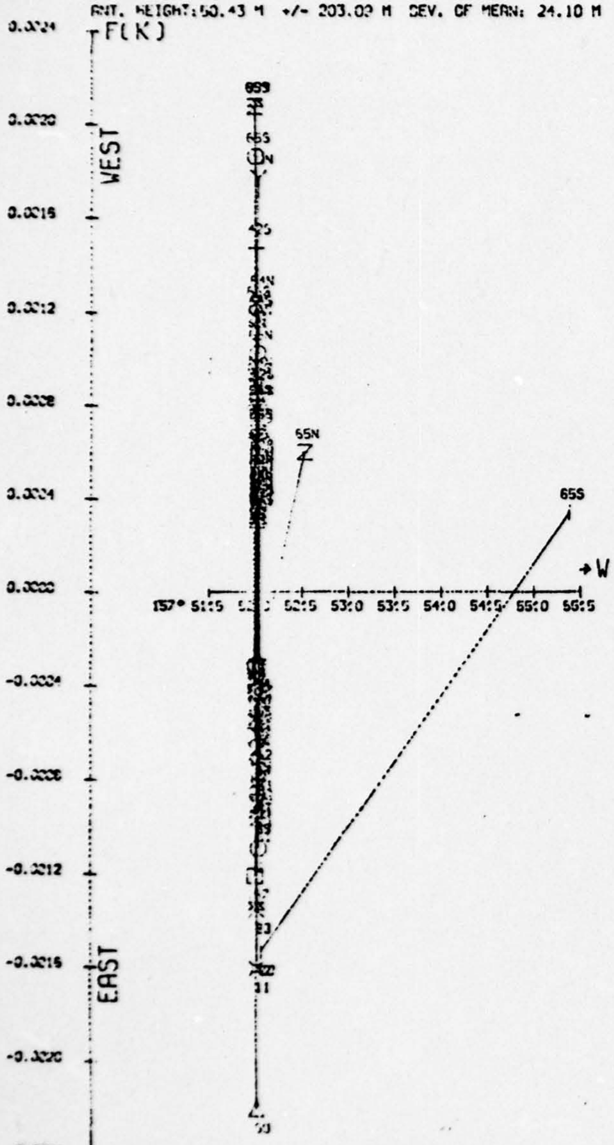


DAY 290-297 1973 KK HNL HT: +24 M # 40 D.C.>10 (3σ)

AUG 26 1976

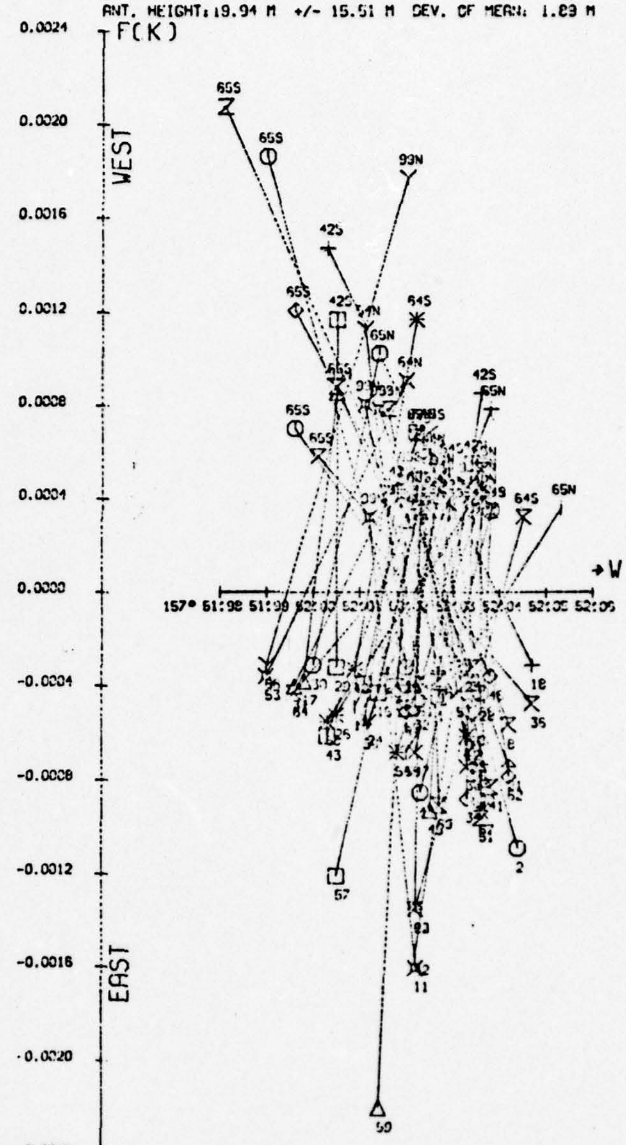
25 26

LAT.: 21° 18:8328 +/- 0:4069 (754.04 M) DEV. OF MEAN: 0:0341 (63.28 M)
LONG.: 157° 52:0537 +/- 0:3281 (566.44 M) 0:0389 (67.22 M)
ANT. HEIGHT: 50.43 M +/- 203.02 M DEV. OF MEAN: 24.10 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C.>4

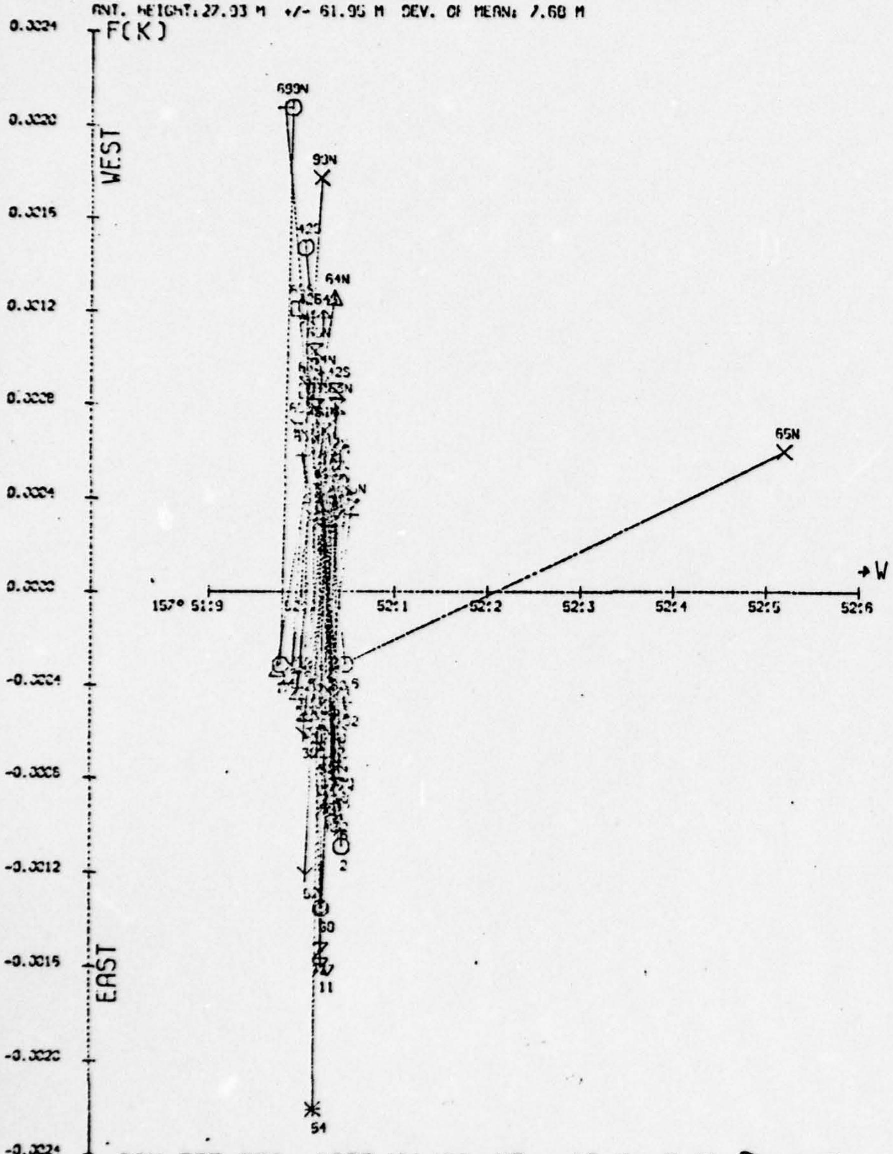
LAT.: 21° 18:8003 +/- 0:0268 (49.66 M) DEV. OF MEAN: 0:0023 (4.23 M)
LONG.: 157° 52:0234 +/- 0:0097 (16.68 M) 0:0012 (2.04 M)
ANT. HEIGHT: 19.94 M +/- 15.51 M DEV. OF MEAN: 1.89 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C.>4 30

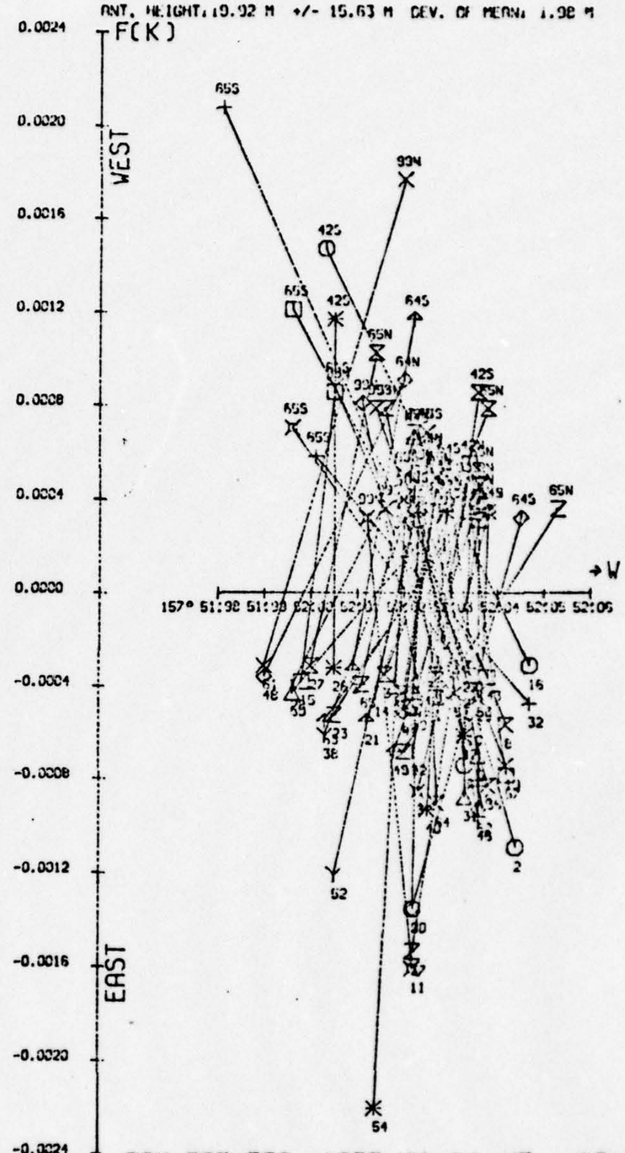
144 1:15

LAT.: 21° 18:7088 +/- 0:0291 (53.85 M) DEV. OF MEAN: 0:0025 (4.72 M)
LONG. 157° 52:0263 +/- 0:0251 (45.01 M) 0:0032 (5.58 M)
ANT. HEIGHT: 27.03 M +/- 61.95 M DEV. OF MEAN: 7.68 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C.75

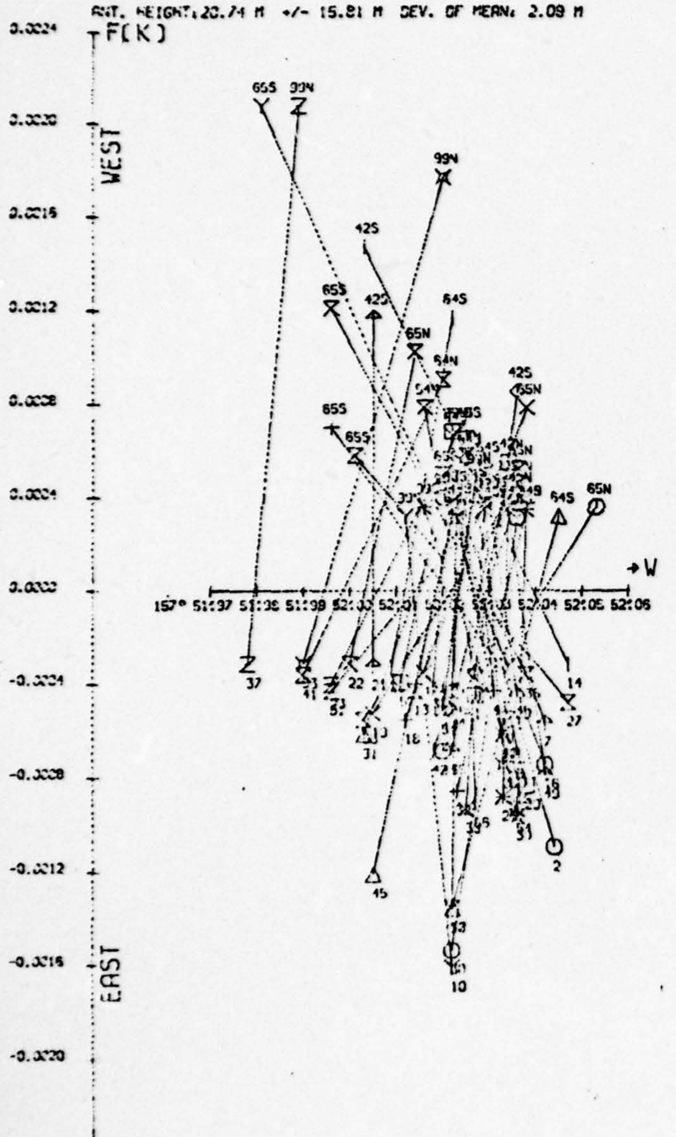
LAT.: 21° 18:8005 +/- 0:0276 (51.16 M) DEV. OF MEAN: 0:0025 (4.53 M)
LONG.. 157° 52:0237 +/- 0:0093 (17.08 M) 0:0013 (2.17 M)
ANT. HEIGHT: 19.92 M +/- 15.63 M DEV. OF MEAN: 1.98 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C.75 36

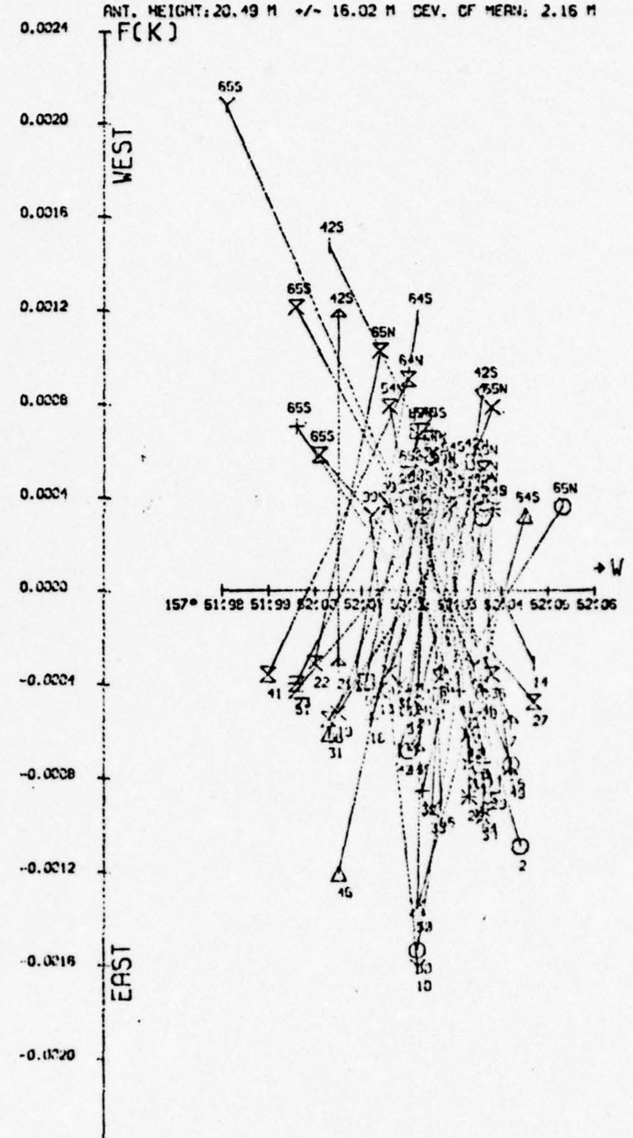
29 30

LAT.: 21° 18:8010 +/- 0:0275 (50.93 M) DEV. OF MEAN: 0:0026 (4.77 M)
LONG. 157° 52:0232 +/- 0:0113 (19.51 M) 0:0015 (2.58 M)
ANT. HEIGHT: 20.74 M +/- 15.81 M DEV. OF MEAN: 2.09 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C>6

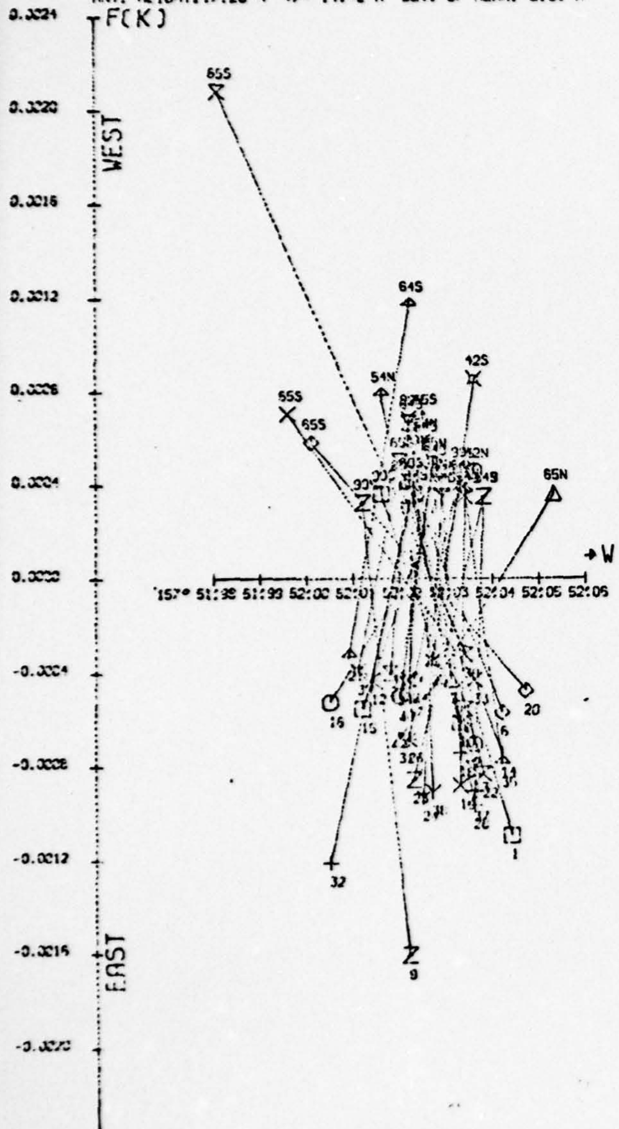
LAT.: 21° 18:8022 +/- 0:0273 (50.56 M) DEV. OF MEAN: 0:0026 (4.82 M)
LONG.: 157° 52:0245 +/- 0:0089 (15.43 M) 0:0012 (2.08 M)
ANT. HEIGHT: 20.49 M +/- 16.02 M DEV. OF MEAN: 2.16 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C>6 30

32

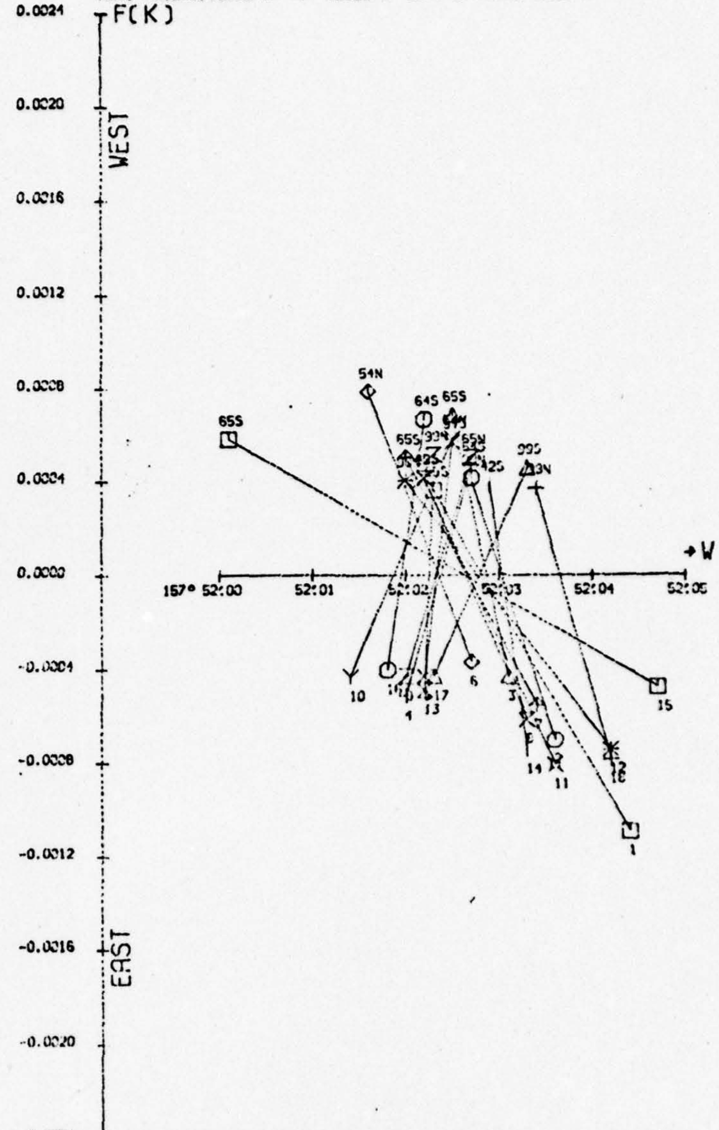
LAT.: 21° 18:8015 +/- 0:0280 (53.31 M) DEV. OF MEAN: 0:0033 (6.04 M)
LONG.. 157° 52:0258 +/- 0:0052 (10.70 M) 0:0010 (1.71 M)
ANT. HEIGHT: 17.28 M +/- 14.42 M DEV. OF MEAN: 2.31 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C>8 (3σ)

34

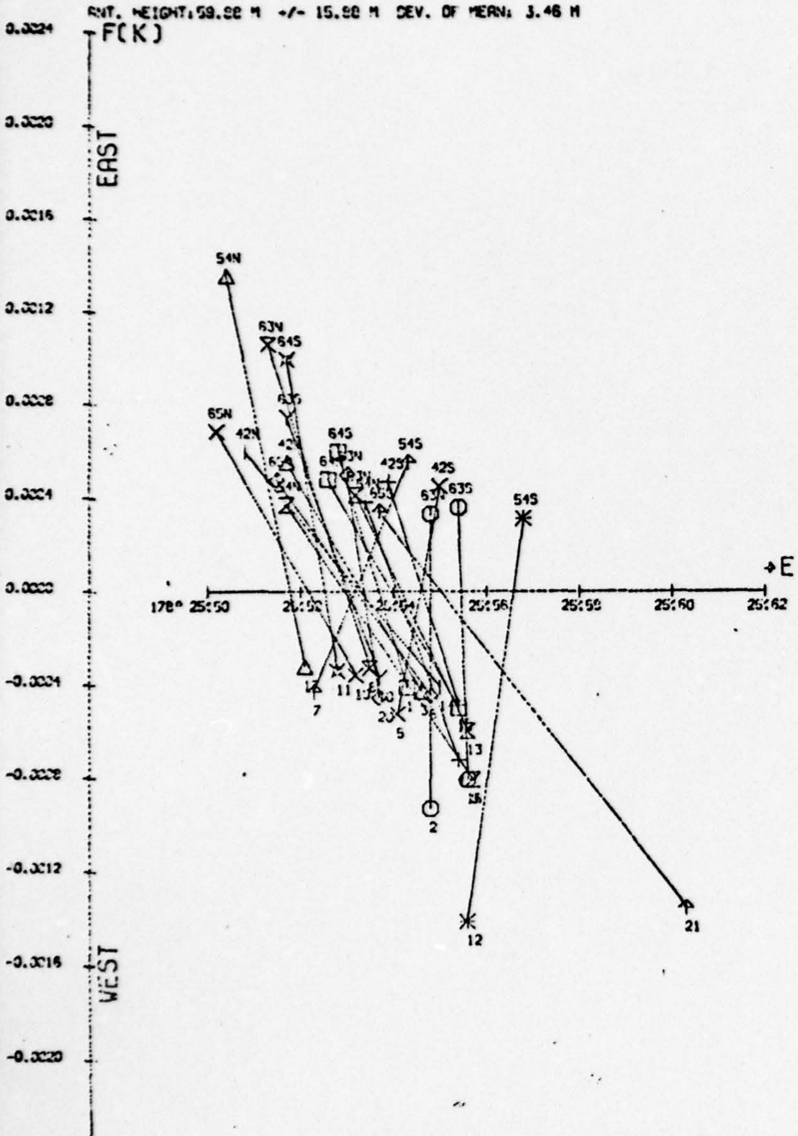
LAT.: 21° 18:8022 +/- 0:0280 (51.82 M) DEV. OF MEAN: 0:0047 (8.64 M)
LONG.. 157° 52:0261 +/- 0:0042 (7.30 M) 0:0010 (1.72 M)
ANT. HEIGHT: 13.75 M +/- 12.20 M DEV. OF MEAN: 2.83 M



DAY 353-372 1973 KK HNL HT: +19 M # 41 D.C>10 (3σ)

132

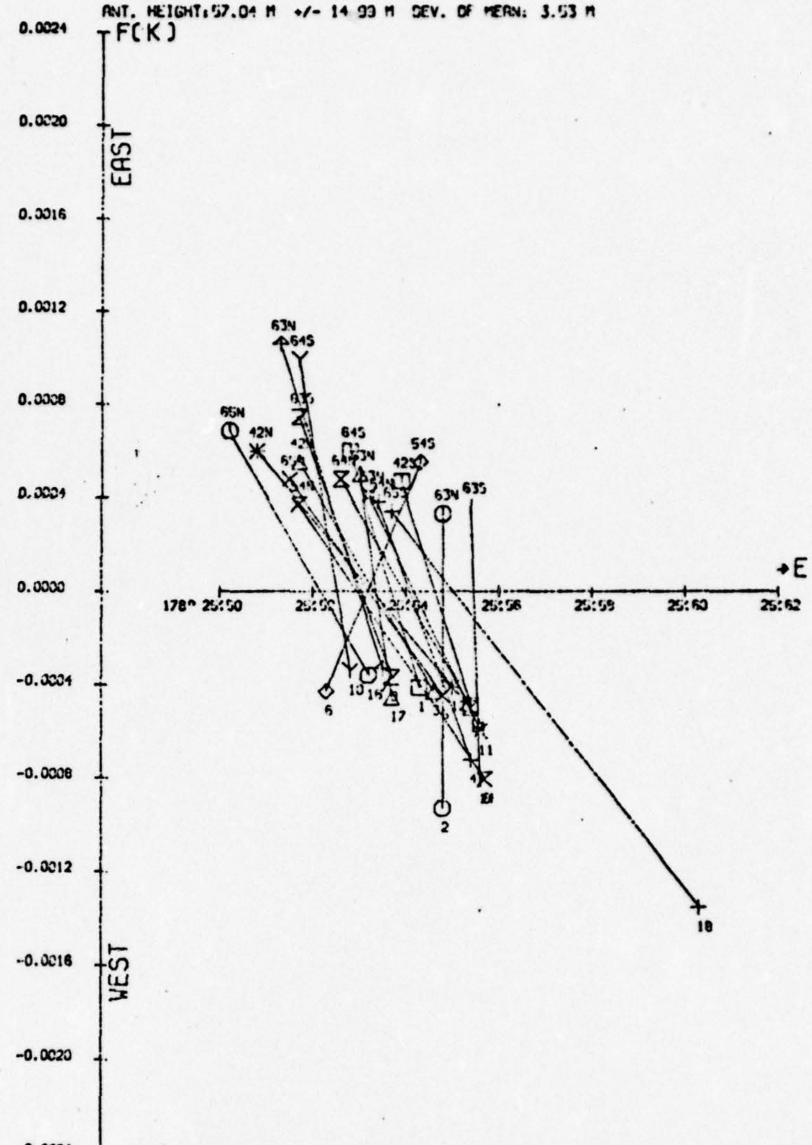
LAT.: -18° 7:7769 +/- 0:0237 (43.95 M) DEV. OF MEAN: 0:0037 (6.78 M)
LONG. 178° 25:5375 +/- 0:0115 (20.21 M) 0:0025 (4.41 M)
ANT. HEIGHT: 59.88 M +/- 15.98 M DEV. OF MEAN: 3.46 M



DAY 202-207 1971 KK SUVA HT: +75 M # 13 D.C.>5 (3σ)

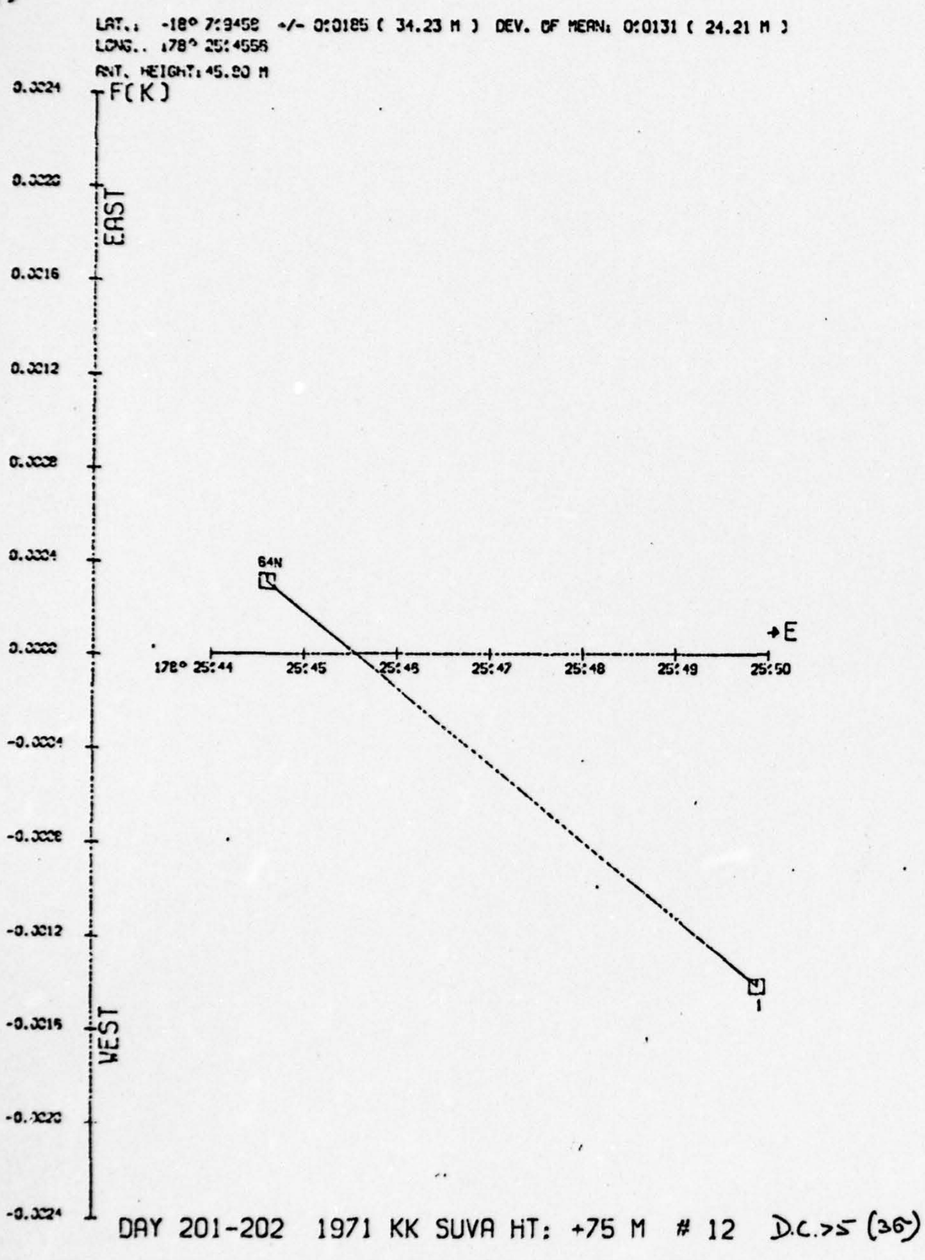
146

LAT.: -18° 7:7781 +/- 0:0242 (44.83 M) DEV. OF MEAN: 0:0040 (7.47 M)
LONG.. 178° 25:5366 +/- 0:0089 (15.73 M) 0:0021 (3.71 M)
ANT. HEIGHT: 57.04 M +/- 14.93 M DEV. OF MEAN: 3.53 M



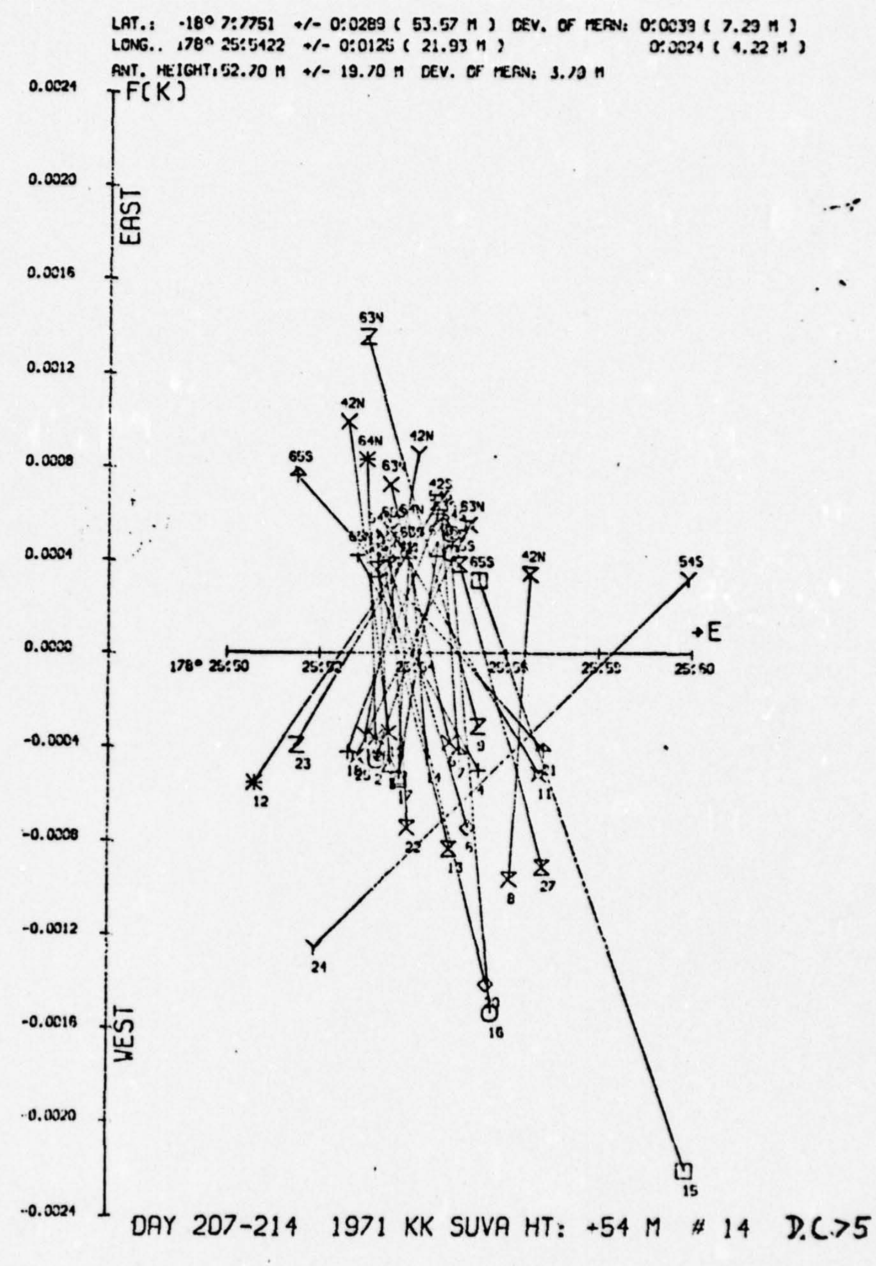
DAY 202-207 1971 KK SUVA HT: +75 M # 13 D.C.>8 (3σ)

131



D.C.>5 (36)

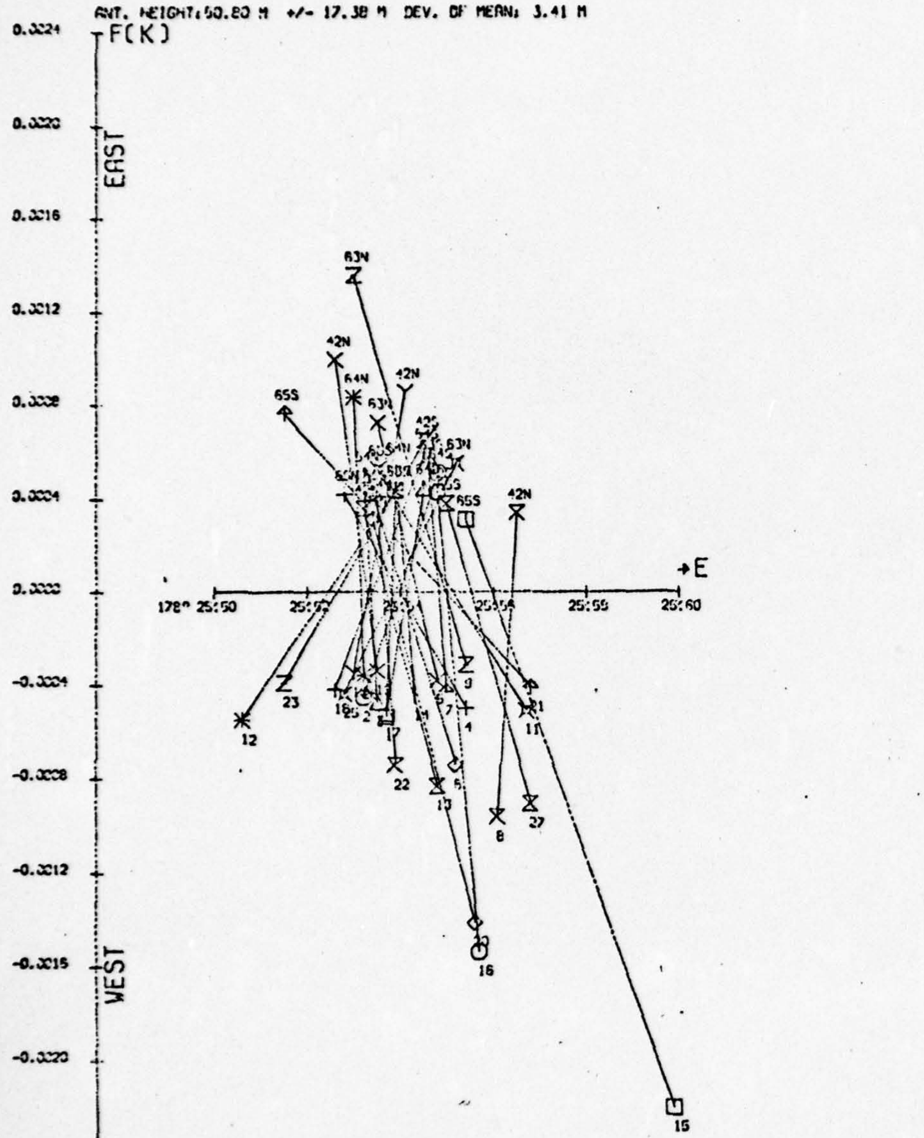
133



D.C.>5

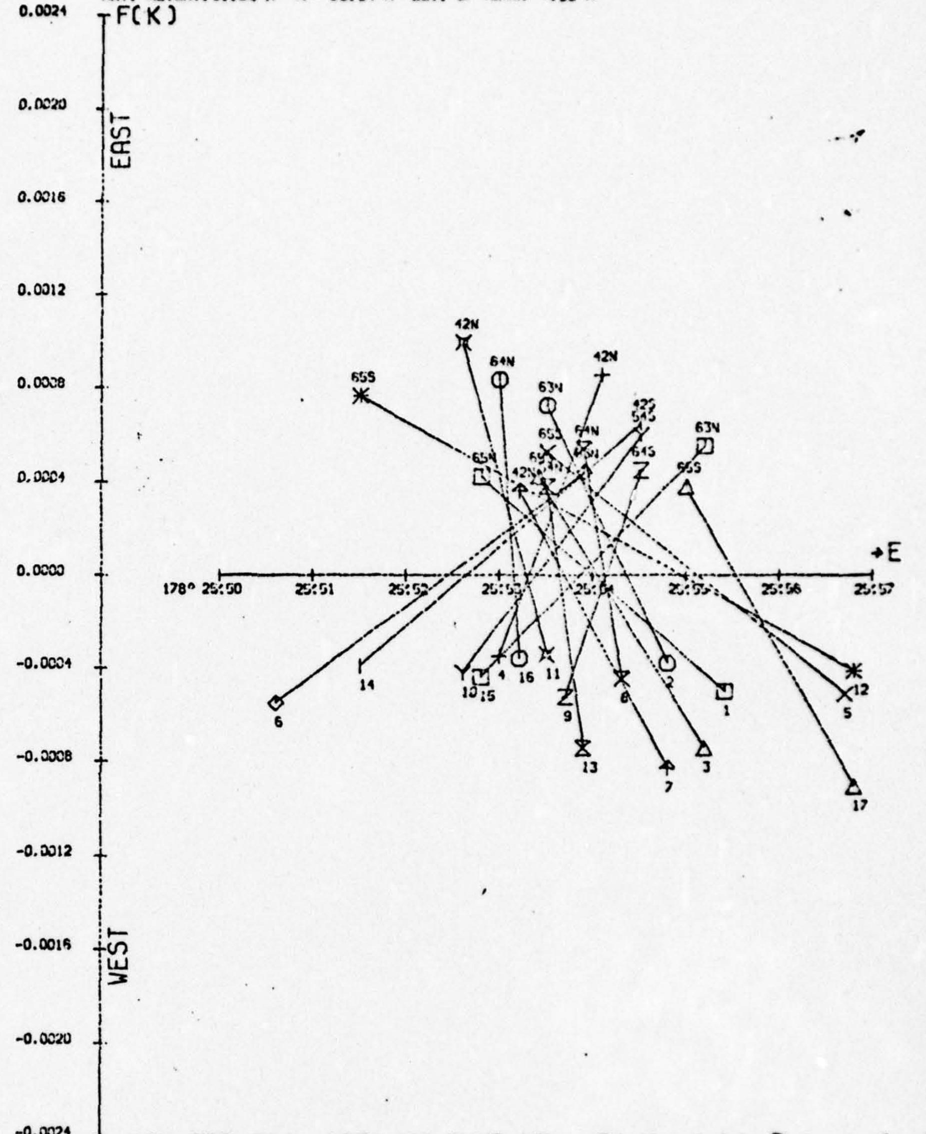
131 147

LAT.: -18° 7:7771 +/- 0:0277 (51.39 M) DEV. OF MEAN: 0:0038 (7.13 M)
LONG.. 178° 25:5408 +/- 0:0008 (17.20 M) 0:0019 (3.37 M)
ANT. HEIGHT: 50.80 M +/- 17.38 M DEV. OF MEAN: 3.41 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 D.C.>5 36

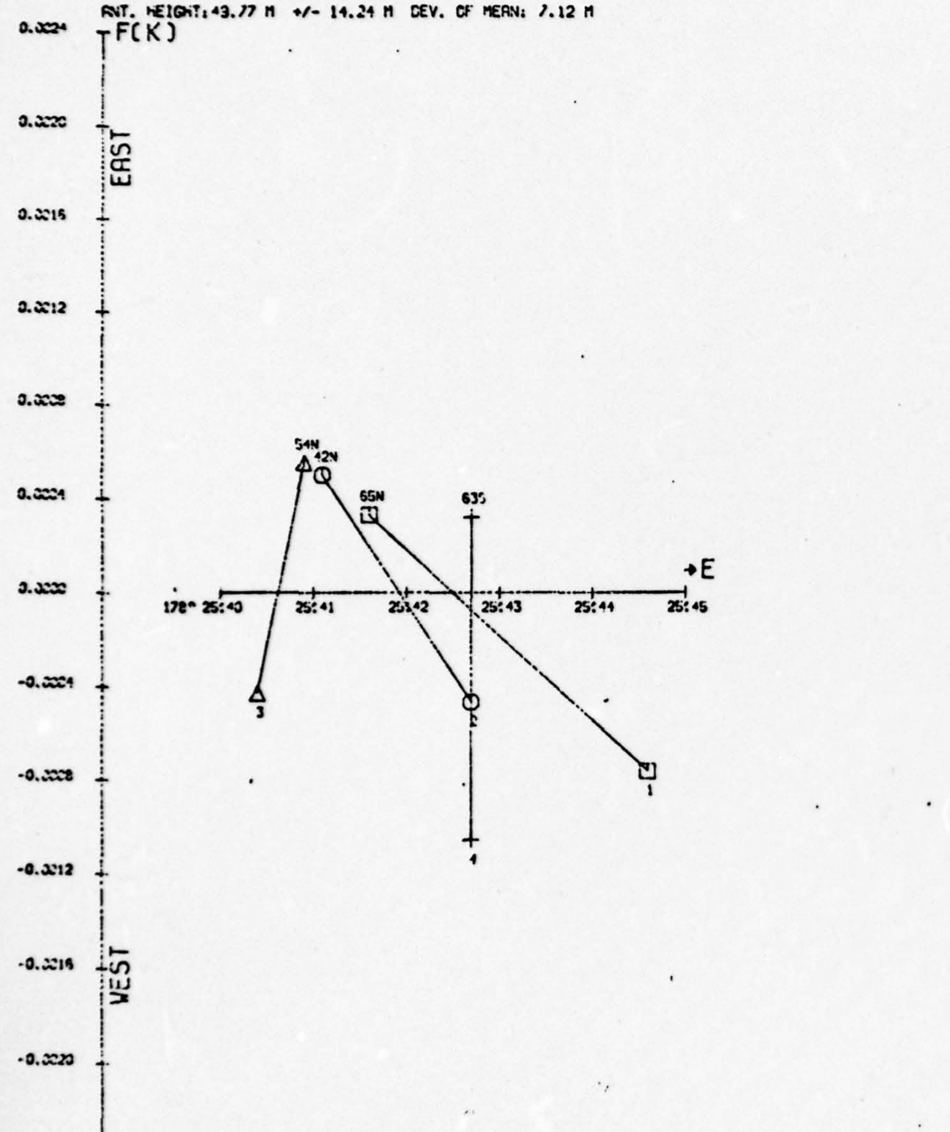
LAT.: -18° 7:7795 +/- 0:0204 (52.65 M) DEV. OF MEAN: 0:0049 (9.03 M)
LONG.. 178° 25:5378 +/- 0:0083 (14.68 M) 0:0020 (3.56 M)
ANT. HEIGHT: 51.06 M +/- 20.54 M DEV. OF MEAN: 4.90 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 D.C.>8 (36)

135

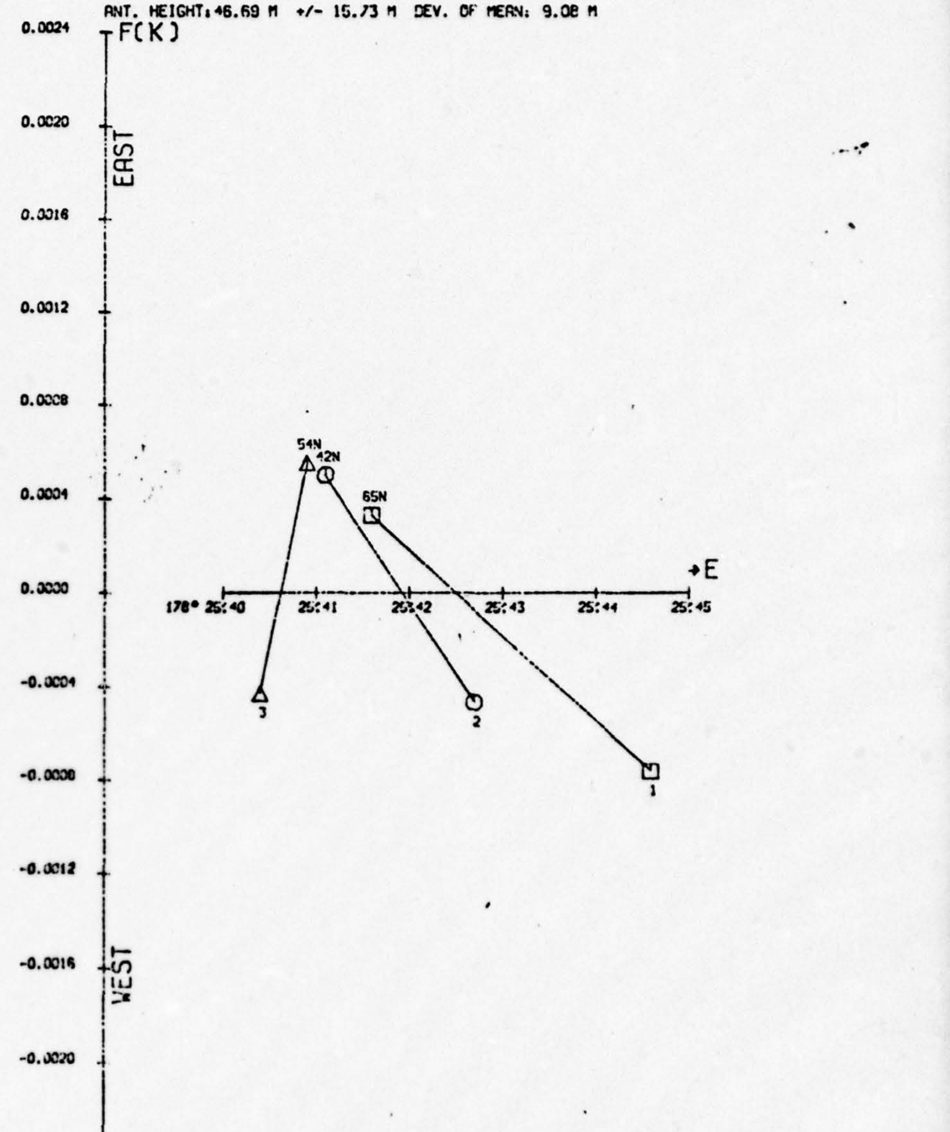
LAT.: -18° 8:0061 +/- 0:0103 (19.04 M) DEV. OF MEAN: 0:0036 (6.73 M)
LONG.. 178° 25:4194 +/- 0:0094 (16.53 M) 0:0047 (8.27 M)
ANT. HEIGHT: 43.77 M +/- 14.24 M DEV. OF MEAN: 7.12 M



DAY 359-360 1972 KK SUVA HT: +59 M # 28 D.C>5 (3σ)

147

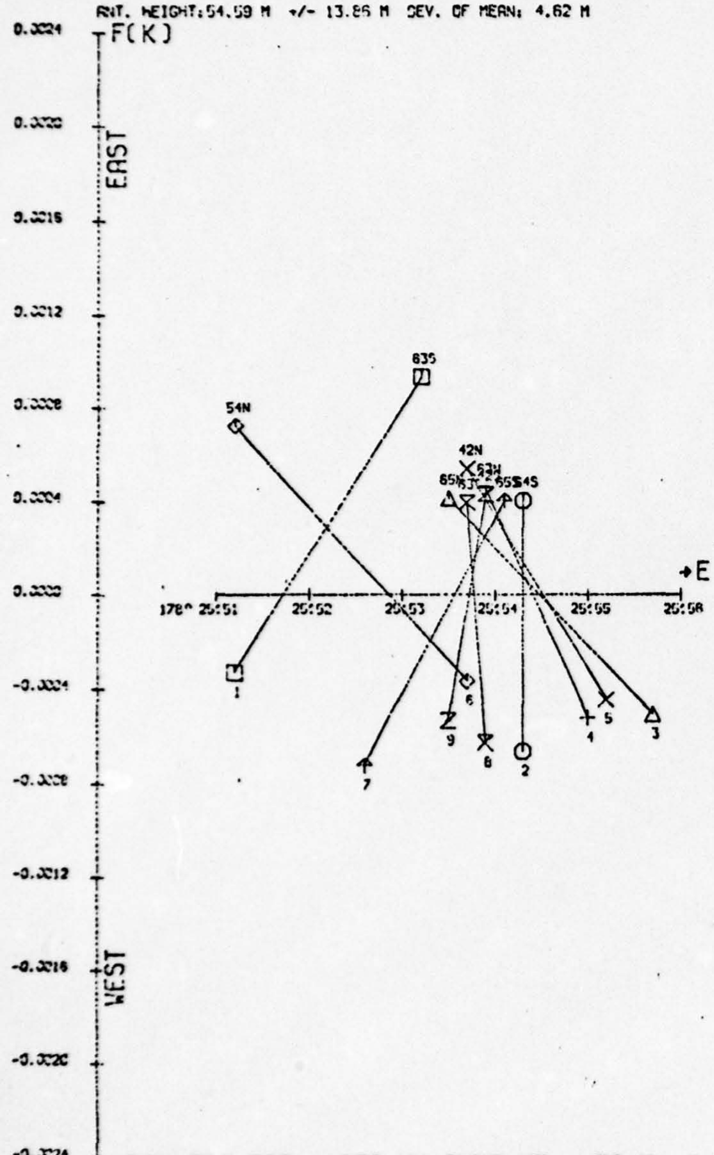
LAT.: -18° 8:0068 +/- 0:0119 (22.05 M) DEV. OF MEAN: 0:0049 (9.01 M)
LONG.: 178° 25:4168 +/- 0:0097 (17.03 M) 0:0056 (9.83 M)
ANT. HEIGHT: 46.69 M +/- 15.73 M DEV. OF MEAN: 9.08 M



DAY 359-360 1972 KK SUVA HT: +59 M # 28 D.C>8 (3σ)

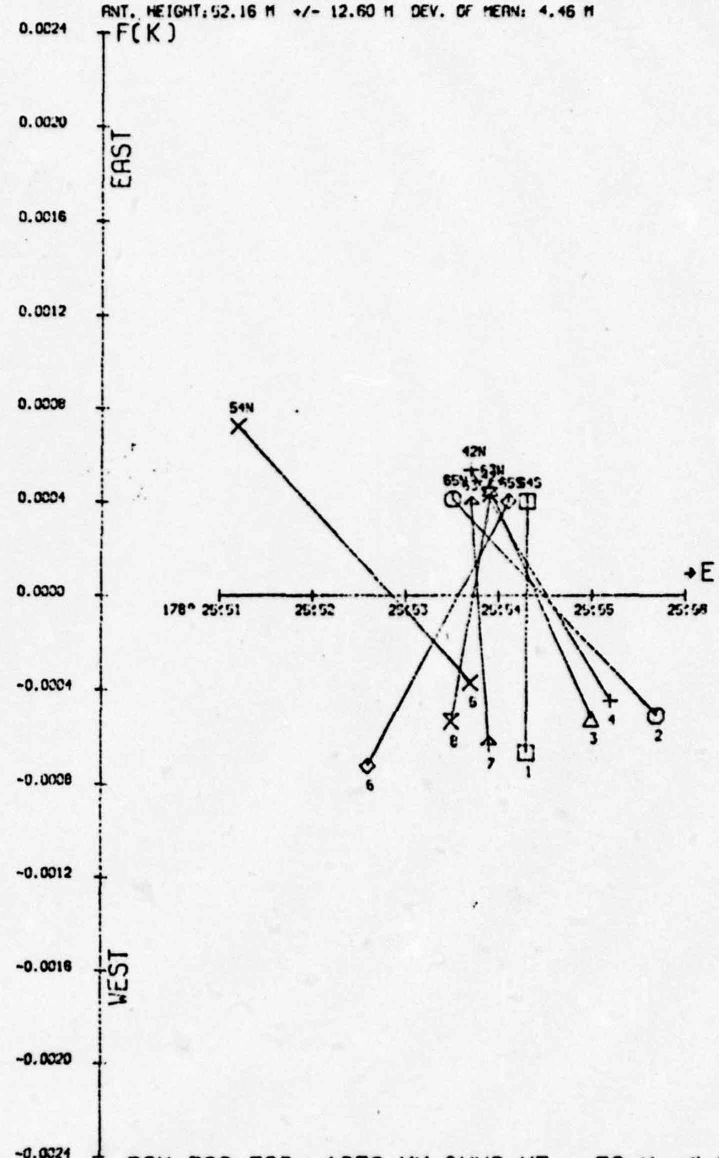
136 119

LAT.: -18° 7:7771 +/- 0:0121 (22.46 M) DEV. OF MEAN: 0:0029 (5.29 M)
LONG.: 178° 25:5370 +/- 0:0092 (16.23 M) 0:0031 (5.41 M)
ANT. HEIGHT: 54.59 M +/- 13.86 M DEV. OF MEAN: 4.62 M



DAY 360-362 1972 KK SUVA HT: +59 M # 29 D.C>5 (3σ)

LAT.: -18° 7:7786 +/- 0:0119 (21.99 M) DEV. OF MEAN: 0:0030 (5.50 M)
LONG.: 178° 25:5395 +/- 0:0058 (10.26 M) 0:0021 (3.63 M)
ANT. HEIGHT: 52.16 M +/- 12.60 M DEV. OF MEAN: 4.46 M

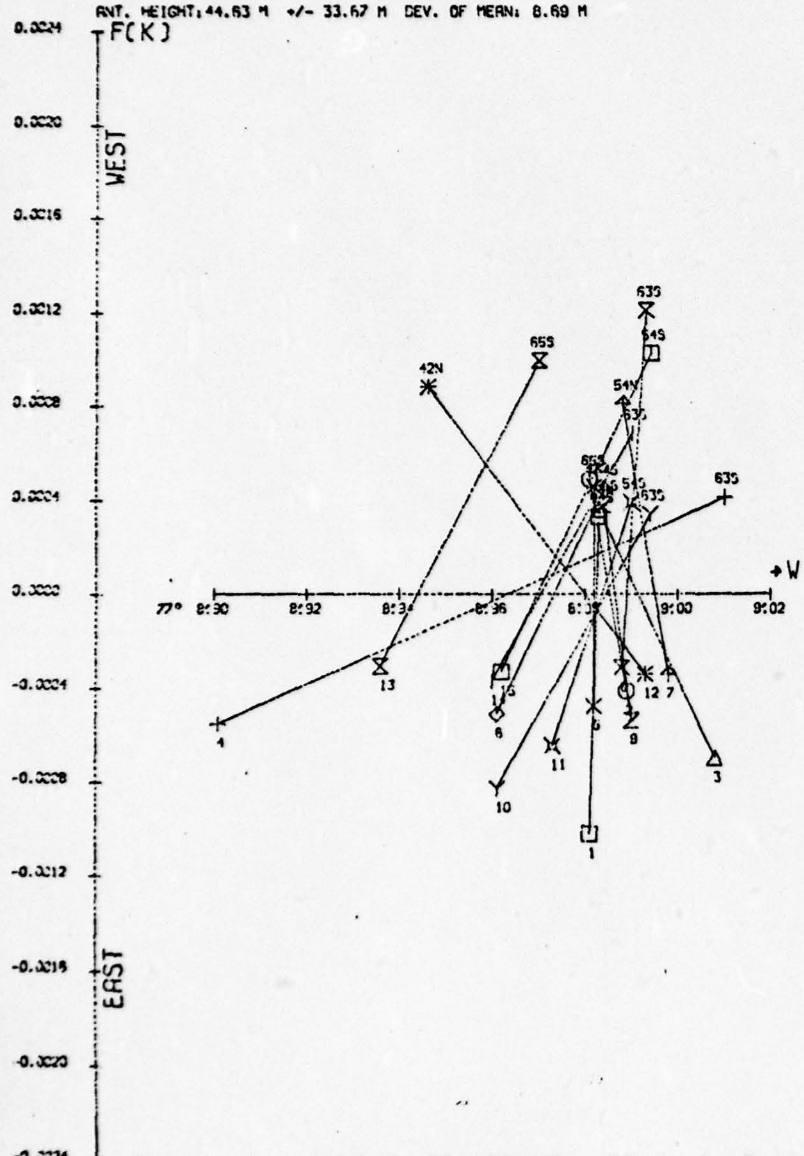


DAY 360-362 1972 KK SUVA HT: +59 M # 29 D.C>8 (3σ)

158

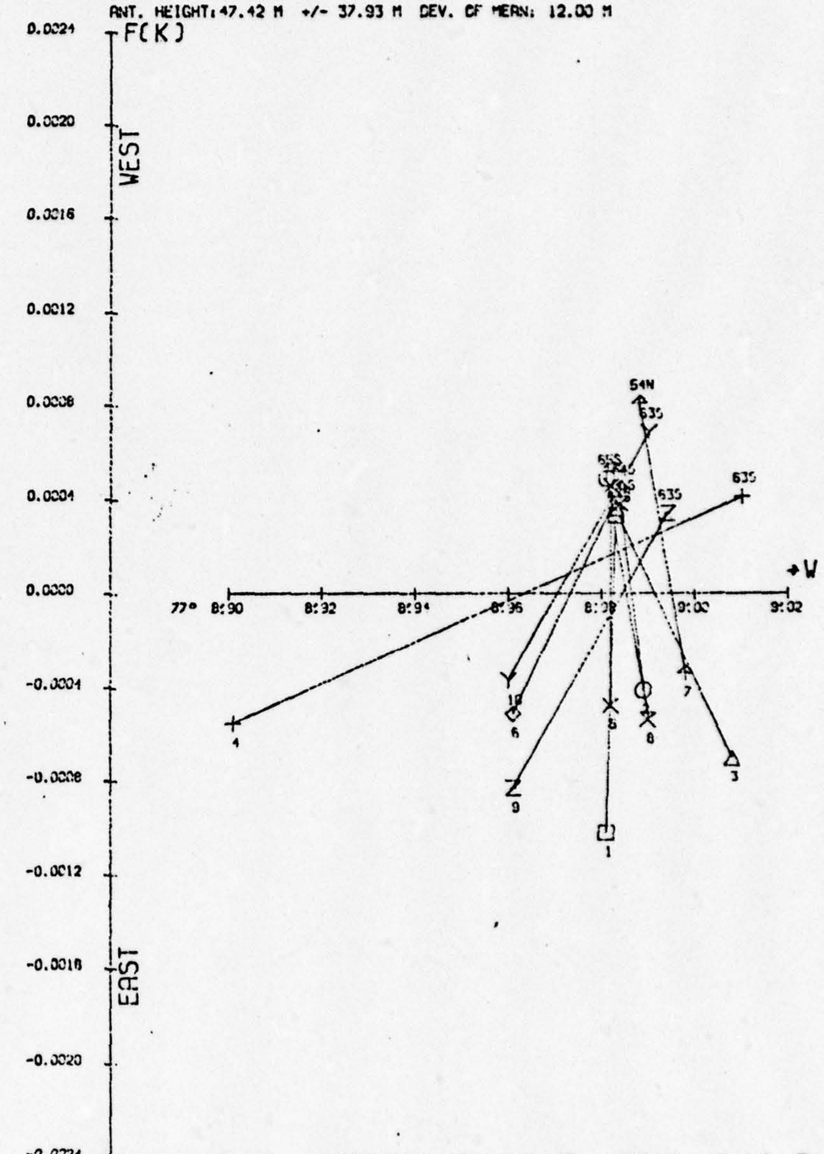
163

LAT.: -12° 3:3184 +/- 0:0298 (55.16 M) DEV. OF MEAN: 0:0054 (10.07 M)
LONG.. 77° 8:9787 +/- 0:0123 (23.42 M) 0:0033 (6.05 M)
ANT. HEIGHT: 44.63 M +/- 33.67 M DEV. OF MEAN: 8.69 M



DAY 15-22 1972 KK CALLAO HT: +33 M # 16 D.C.>5 (3σ)

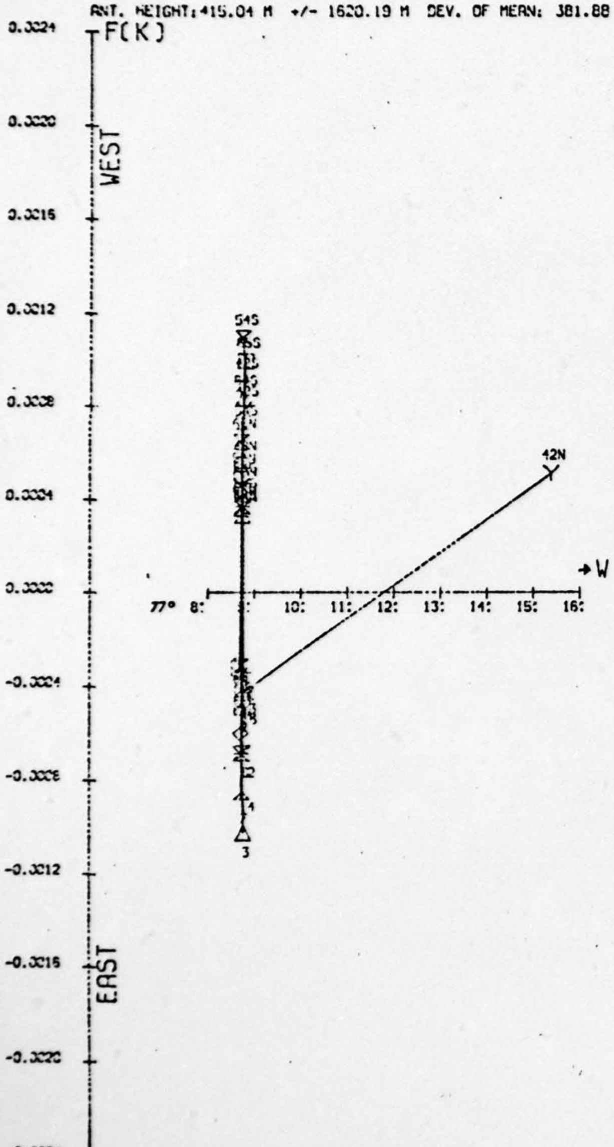
LAT.: -12° 3:3154 +/- 0:0255 (47.17 M) DEV. OF MEAN: 0:0057 (10.55 M)
LONG.. 77° 8:9814 +/- 0:0037 (17.58 M) 0:0031 (5.56 M)
ANT. HEIGHT: 47.42 M +/- 37.93 M DEV. OF MEAN: 12.00 M



DAY 15-22 1972 KK CALLAO HT: +33 M # 16 D.C.>8 (3σ)

159

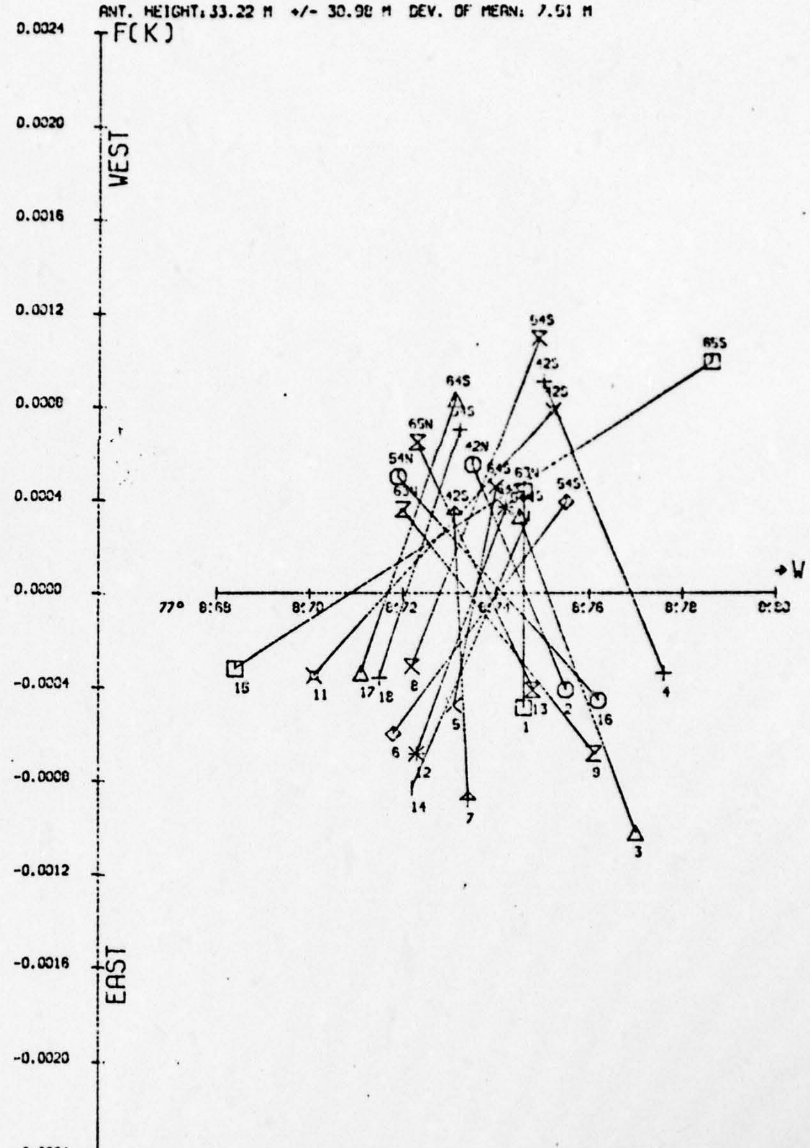
LAT.: -12° 2:9061 +/- 0:8805 (1631.76 M) DEV. OF MEAN: 0:1468 (271.96 M)
LONG.: 77° 8:3043 +/- 0:7170 (1299.42 M) 0:1690 (306.20 M)
ANT. HEIGHT: 415.04 M +/- 1620.19 M DEV. OF MEAN: 381.88 M



DAY 54-58 1972 KK CALLAO HT: +28 M # 17 D.C.>5

160

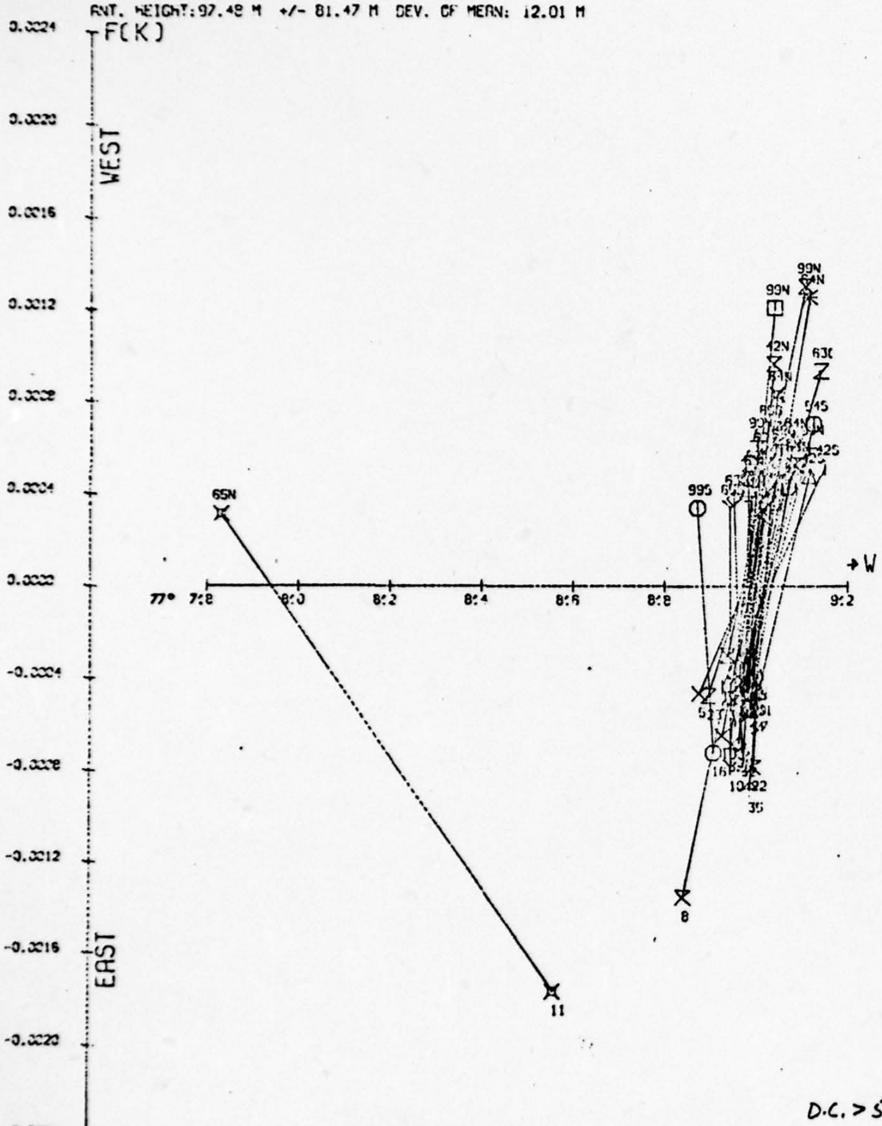
LAT.: -12° 2:8490 +/- 0:1050 (194.55 M) DEV. OF MEAN: 0:0180 (33.36 M)
LONG.: 77° 8:7343 +/- 0:0145 (26.31 M) 0:0035 (6.38 M)
ANT. HEIGHT: 33.22 M +/- 30.98 M DEV. OF MEAN: 7.51 M



DAY 54-58 1972 KK CALLAO HT: +28 M # 17 D.C.>5 36

161

LAT.: -12° 3:2313 +/- 0:1024 (189.92 M) DEV. OF MEAN: 0:0107 (19.79 M)
LONG. 77° 9:9733 +/- 0:1590 (286.36 M) 0:0233 (42.22 M)
ANT. HEIGHT: 97.48 M +/- 81.47 M DEV. OF MEAN: 12.01 M

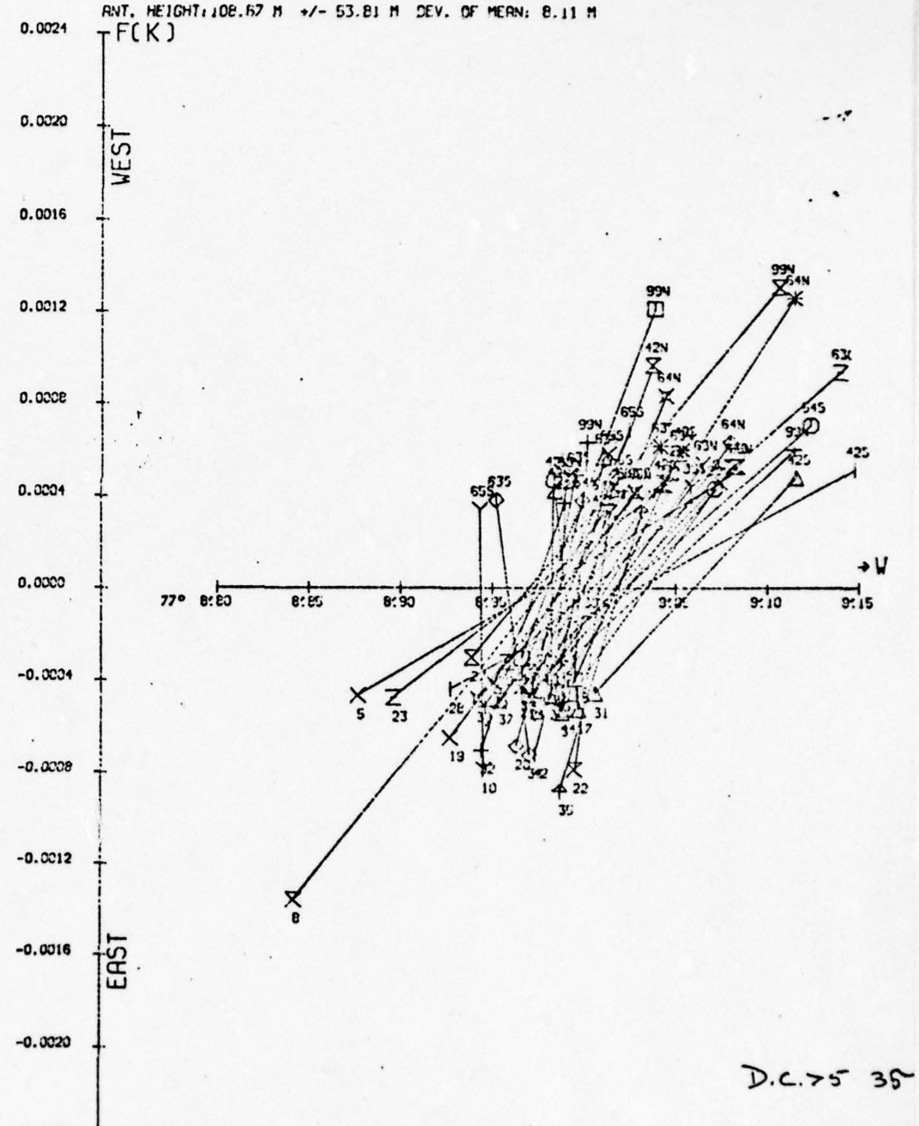


D.C. > 5

DAY 72-90 1974 KK CALLAO SITE 'A' HT: +38 M # 43

162

LAT.: -12° 3:3030 +/- 0:0522 (96.72 M) DEV. OF MEAN: 0:0056 (10.31 M)
LONG.: 77° 8:9987 +/- 0:0223 (40.33 M) 0:0034 (6.08 M)
ANT. HEIGHT: 108.67 M +/- 53.81 M DEV. OF MEAN: 8.11 M



D.C. > 5 35

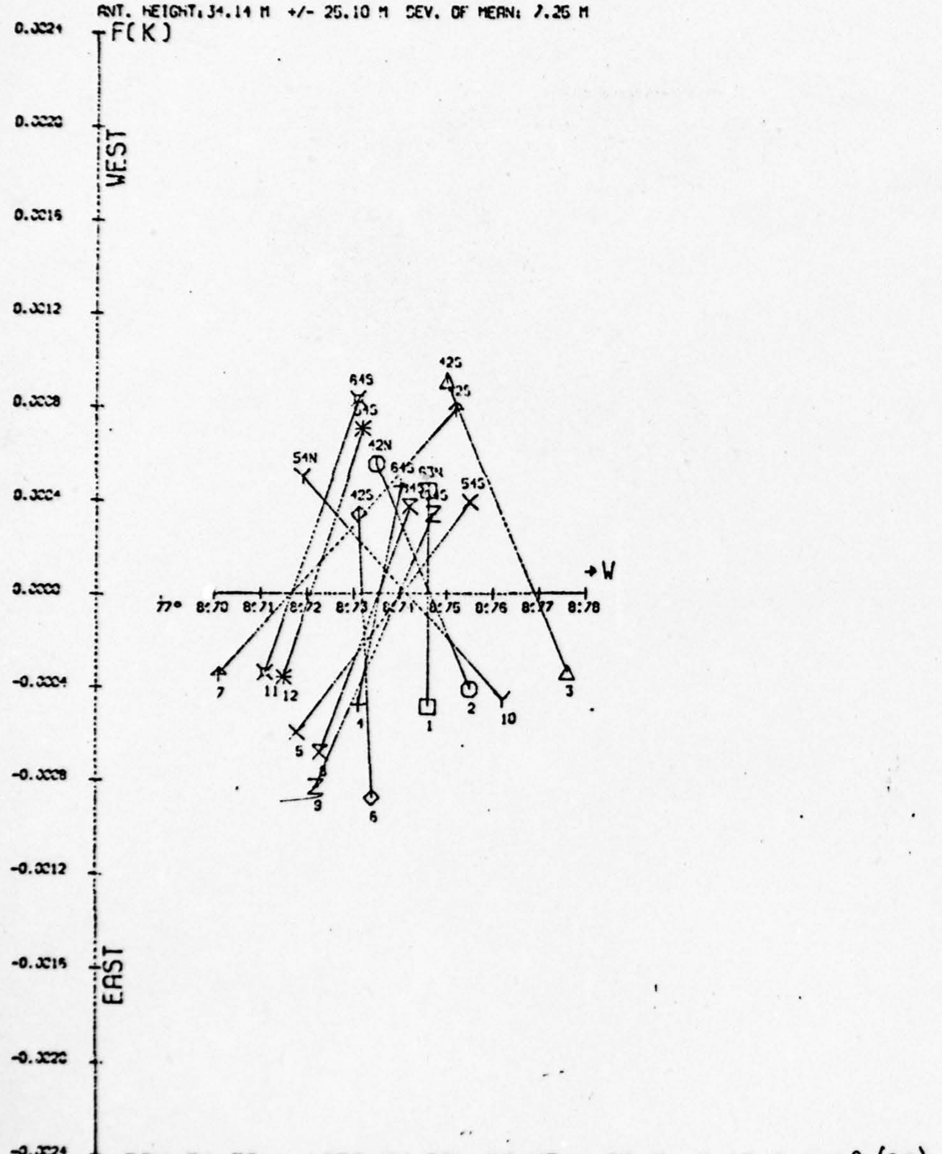
DAY 72-90 1974 KK CALLAO SITE 'A' HT: +38 M # 43

II

164

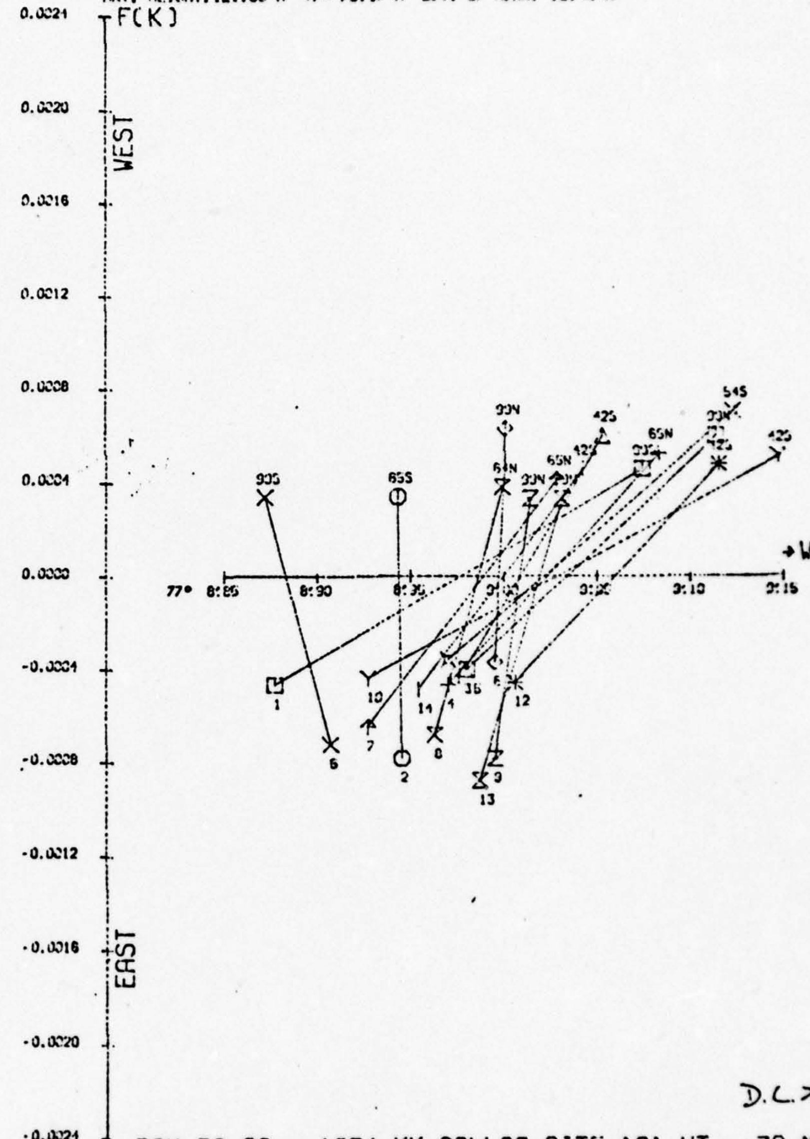
1 Sept. 76 File #33

LAT.: -12° 2:8503 +/- 0:1241 (230.03 M) DEV. OF MEAN: 0:0253 (46.95 M)
LONG.: 77° 8:7357 +/- 0:0146 (26.44 M) 0:0042 (7.63 M)
ANT. HEIGHT: 34.14 M +/- 25.10 M DEV. OF MEAN: 7.26 M



DAY 54-58 1972 KK CALLAO HT: +28 M # 17 D.C.>8 (3σ)

LAT.: -12° 3:3301 +/- 0:0577 (106.87 M) DEV. OF MEAN: 0:0105 (19.51 M)
LONG.: 77° 9:3084 +/- 0:0420 (76.03 M) 0:0108 (19.63 M)
ANT. HEIGHT: 121.05 M +/- 75.37 M DEV. OF MEAN: 13.46 M



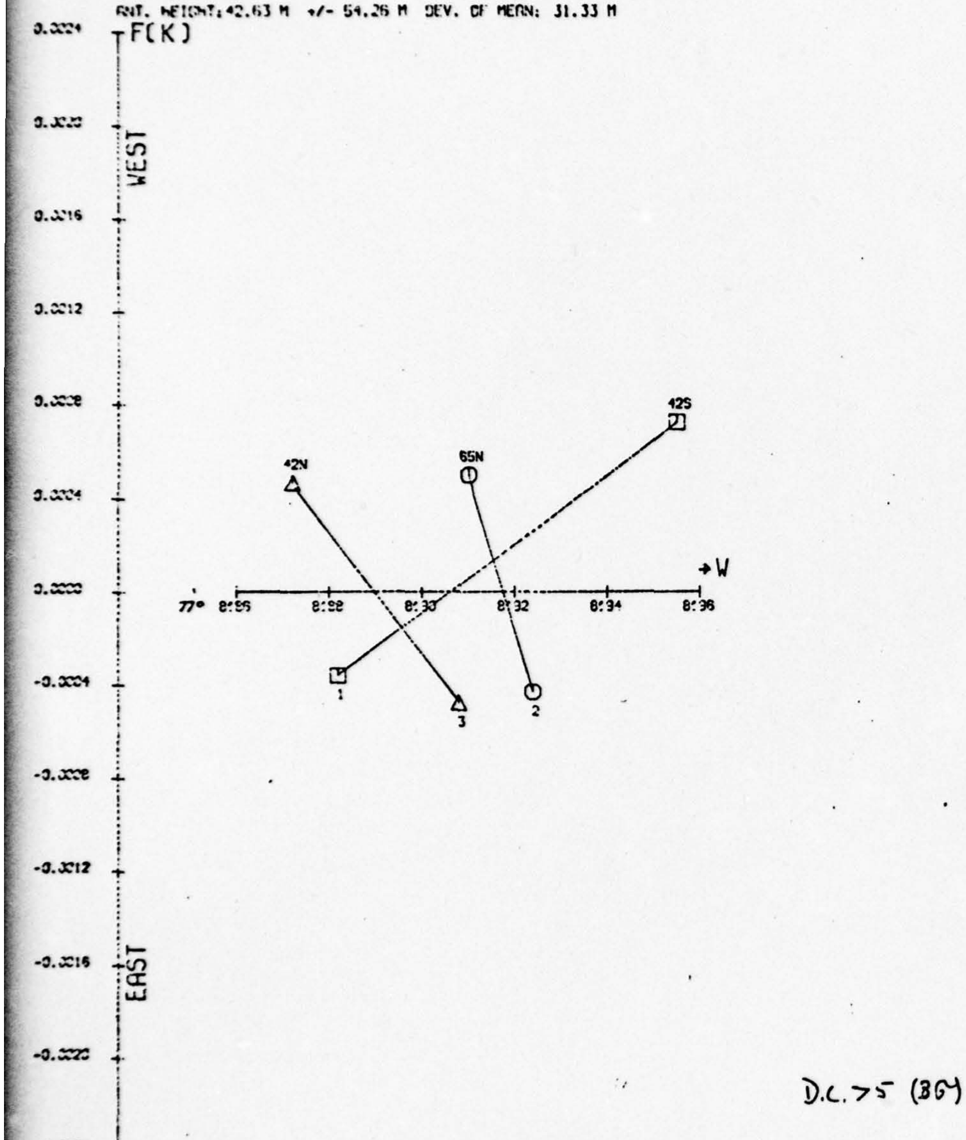
D.C.>8 (3σ)

DAY 72-90 1974 KK CALLAO SITE 'A' HT: +38 M # 43

51

166

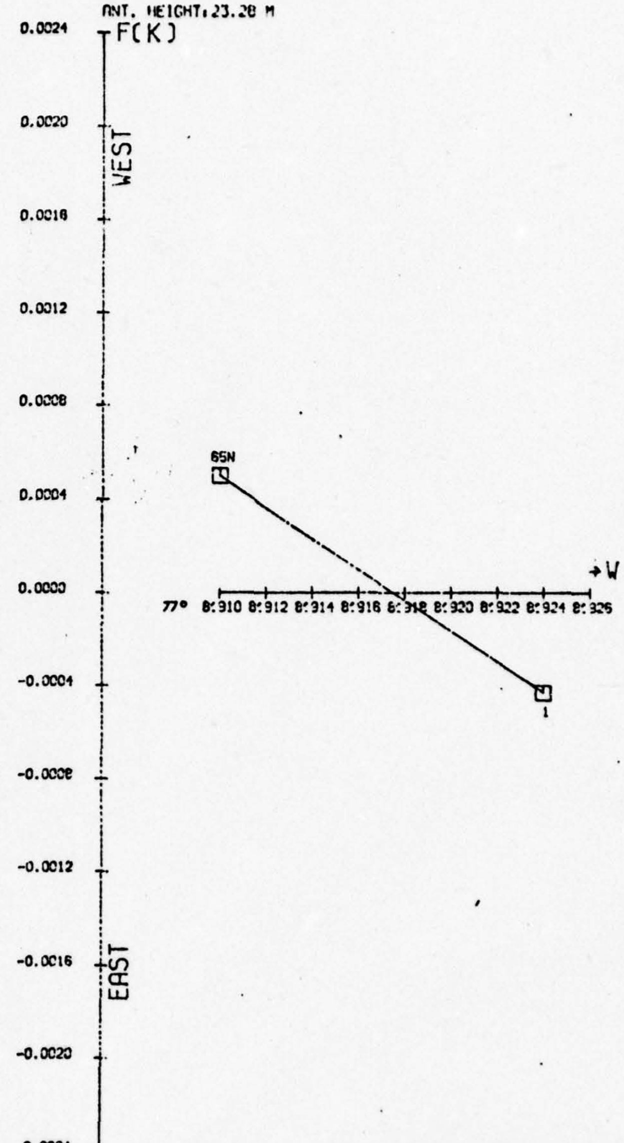
LAT.: -12° 3:2124 +/- 0:0394 (72.98 M) DEV. OF MEAN: 0:0161 (29.79 M)
LONG.. 77° 8:3045 +/- 0:0139 (25.27 M) 0:0080 (14.59 M)
ANT. HEIGHT:42.63 M +/- 54.26 M DEV. OF MEAN: 31.33 M



D.C.>5 (36)

DAY 99-101 1974 KK CALLAO SITE 'D' HT: +38 M # 45

LAT.: -12° 3:1858 +/- 0:0240 (44.47 M) DEV. OF MEAN: 0:0170 (31.44 M)
LONG.. 77° 8:3175
ANT. HEIGHT:23.28 M

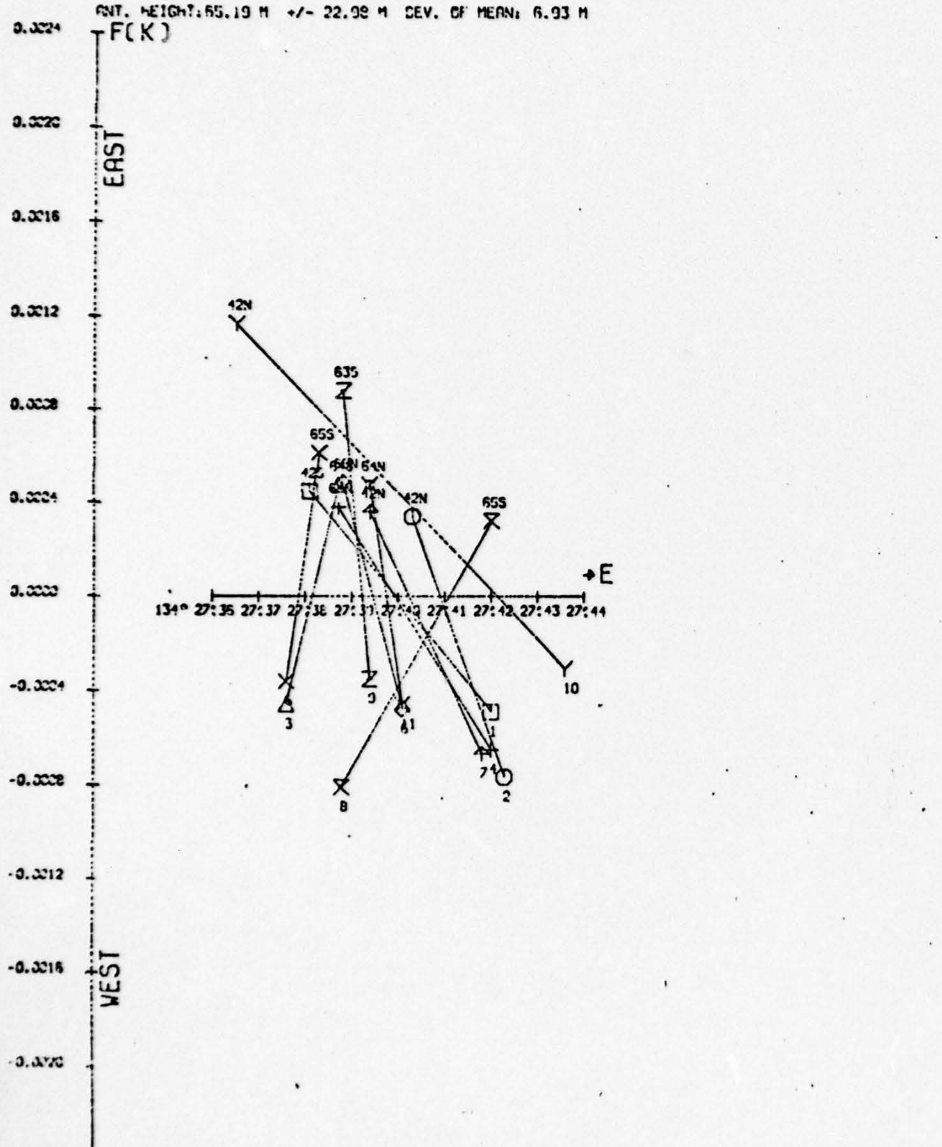


D.C.>8 (35)

DAY 99-101 1974 KK CALLAO SITE 'D' HT: +38 M # 45

157

LAT.: 7° 19:9249 +/- 0:0186 (34.47 M) DEV. OF MEAN: 0:0040 (7.35 M)
LONG.. 134° 27:3992 +/- 0:0125 (22.92 M) 0:0038 (6.91 M)
ANT. HEIGHT: 65.19 M +/- 22.99 M DEV. OF MEAN: 6.93 M

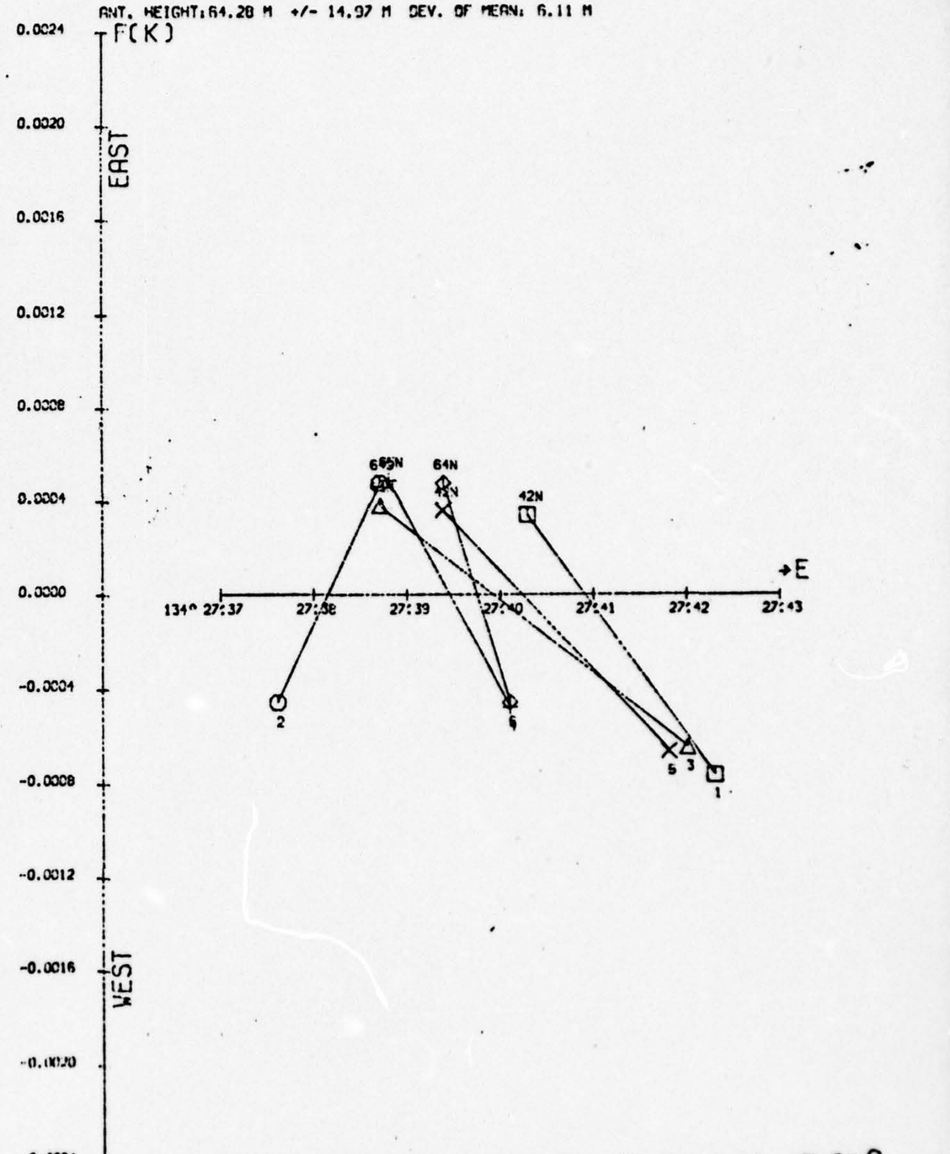


DAY 167-171 1971 KK PALAU HT: +78 M # 11 DC>5 (3σ)

172

COMPLOT

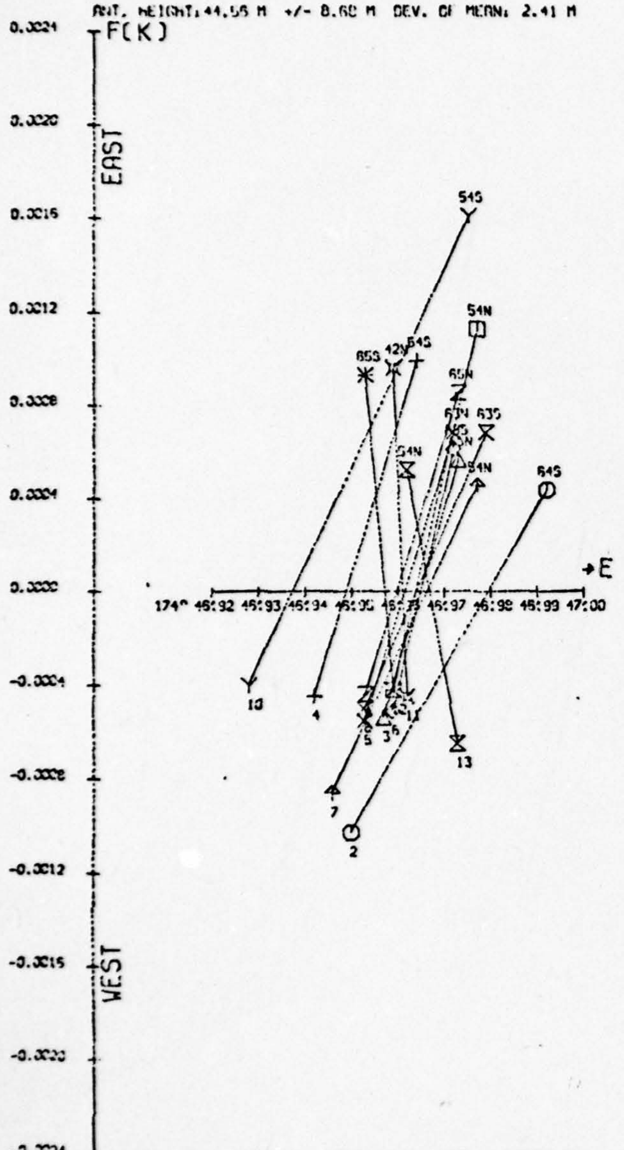
LAT.: 7° 19:8144 +/- 0:0143 (26.49 M) DEV. OF MEAN: 0:0041 (7.65 M)
LONG.. 134° 27:3967 +/- 0:0033 (17.11 M) 0:0038 (6.93 M)
ANT. HEIGHT: 64.28 M +/- 14.97 M DEV. OF MEAN: 6.11 M



DAY 167-171 1971 KK PALAU HT: +78 M # 11 DC>8 (3σ)

155

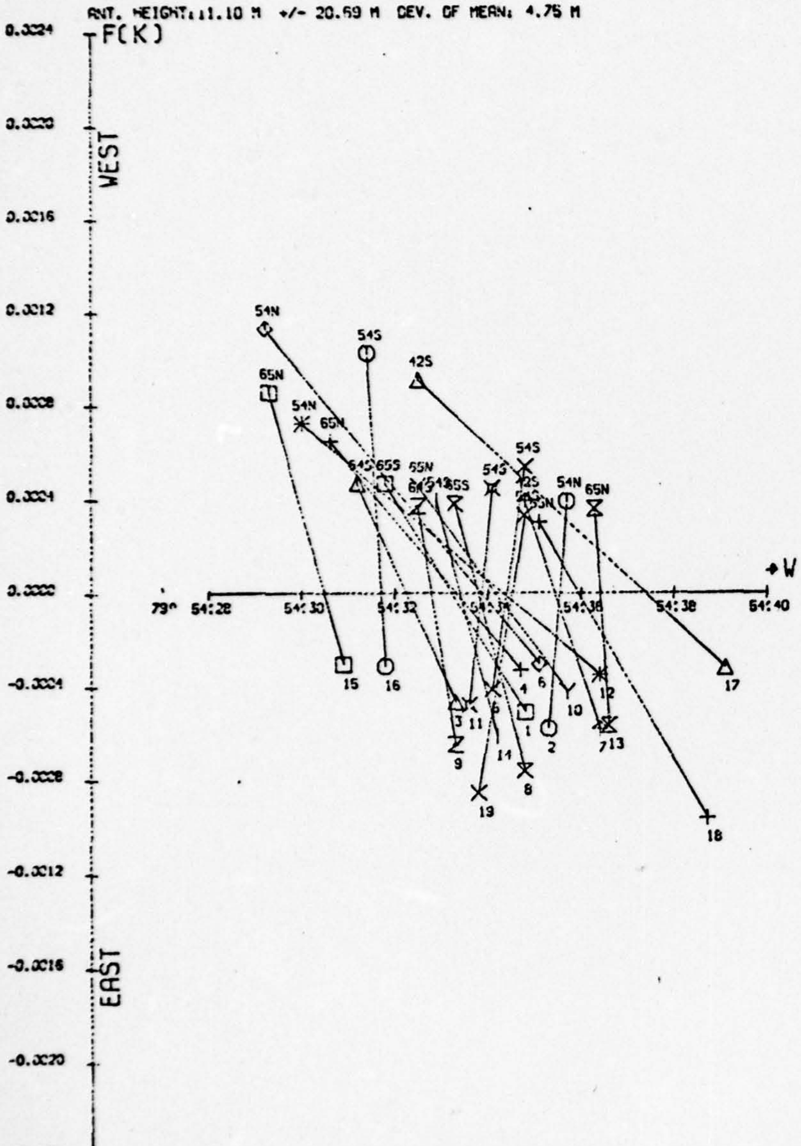
LAT.: -41° 16:9016 +/- 0:0107 (19.91 M) DEV. OF MEAN: 0:0021 (3.90 M)
LONG.: 174° 46:9612 +/- 0:0090 (13.75 M) 0:0027 (3.81 M)
ANT. HEIGHT: 44.56 M +/- 8.60 M DEV. OF MEAN: 2.41 M



DAY 241-244 1971 KK WELLINGTON HT: +35 M # 15 DC>8 DC>5 (3σ)

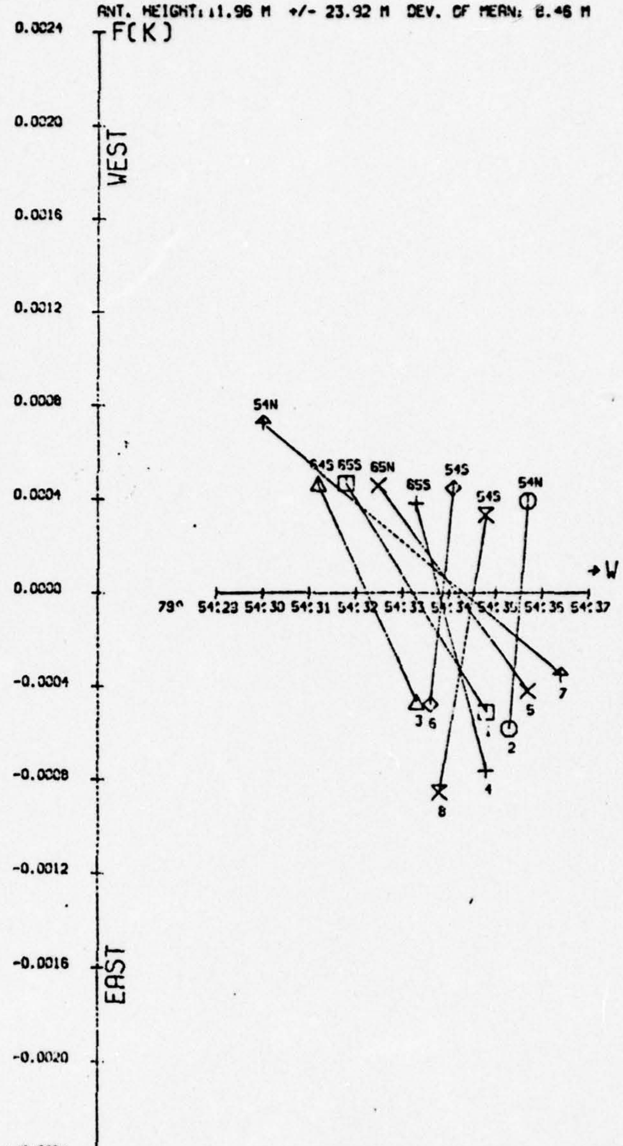
152 167

LAT.: -2° 16:9932 +/- 0:0372 (68.92 M) DEV. OF MEAN: 0:0060 (11.19 M)
LONG.. 79° 54:3404 +/- 0:0156 (30.77 M) 0:0038 (7.06 M)
ANT. HEIGHT: 11.10 M +/- 20.69 M DEV. OF MEAN: 4.75 M



DAY 104-111 1972 KK GUAYAQUIL HT: +30 M # 20 DC>5 (3σ)

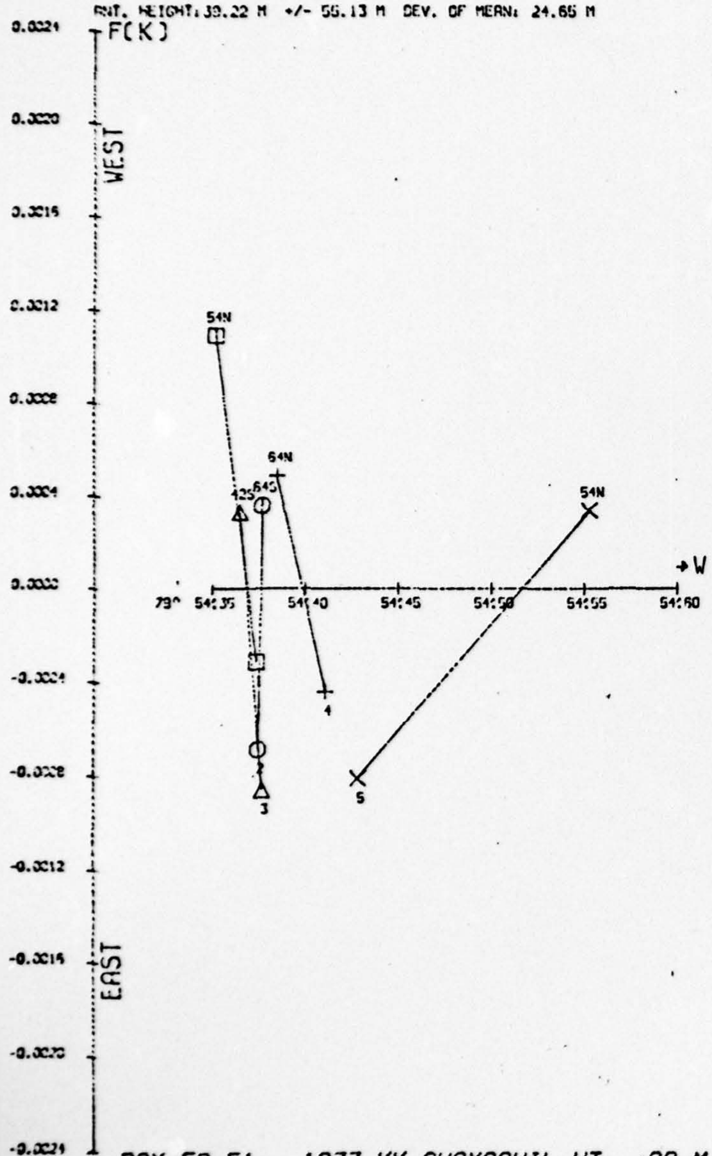
LAT.: -2° 16:9908 +/- 0:0237 (43.95 M) DEV. OF MEAN: 0:0059 (10.99 M)
LONG.. 79° 54:3395 +/- 0:0096 (17.81 M) 0:0034 (6.30 M)
ANT. HEIGHT: 11.96 M +/- 23.92 M DEV. OF MEAN: 8.46 M



DAY 104-111 1972 KK GUAYAQUIL HT: +30 M # 20 DC>8 (3σ)

154

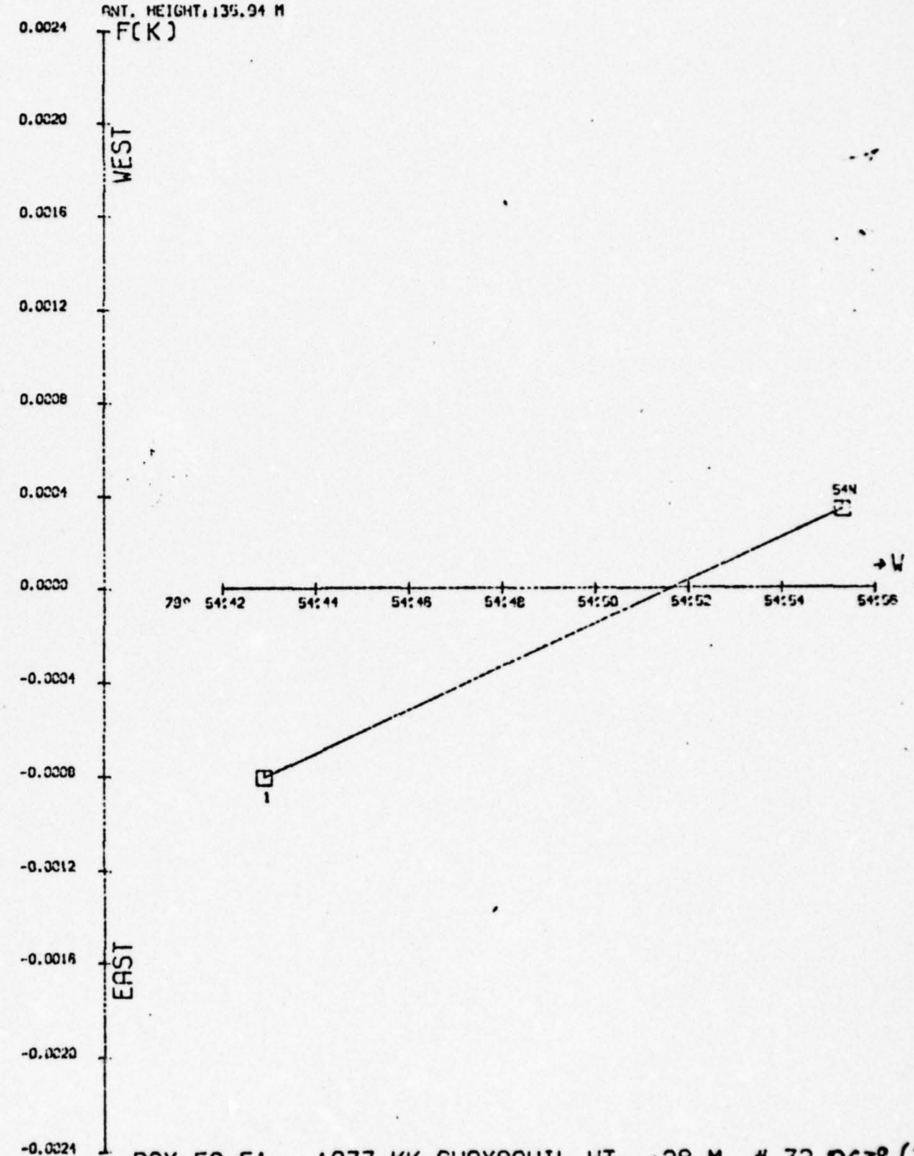
LAT.: -2° 16:9334 +/- 0:1105 (204.77 M) DEV. OF MEAN: 0:0349 (64.75 M)
LONG.: 79° 54:4057 +/- 0:0630 (116.65 M) 0:0282 (52.17 M)
ANT. HEIGHT: 39.22 M +/- 55.13 M DEV. OF MEAN: 24.65 M



DAY 50-51 1973 KK GUAYAQUIL HT: +28 M # 32 DC>5 (3σ)

169

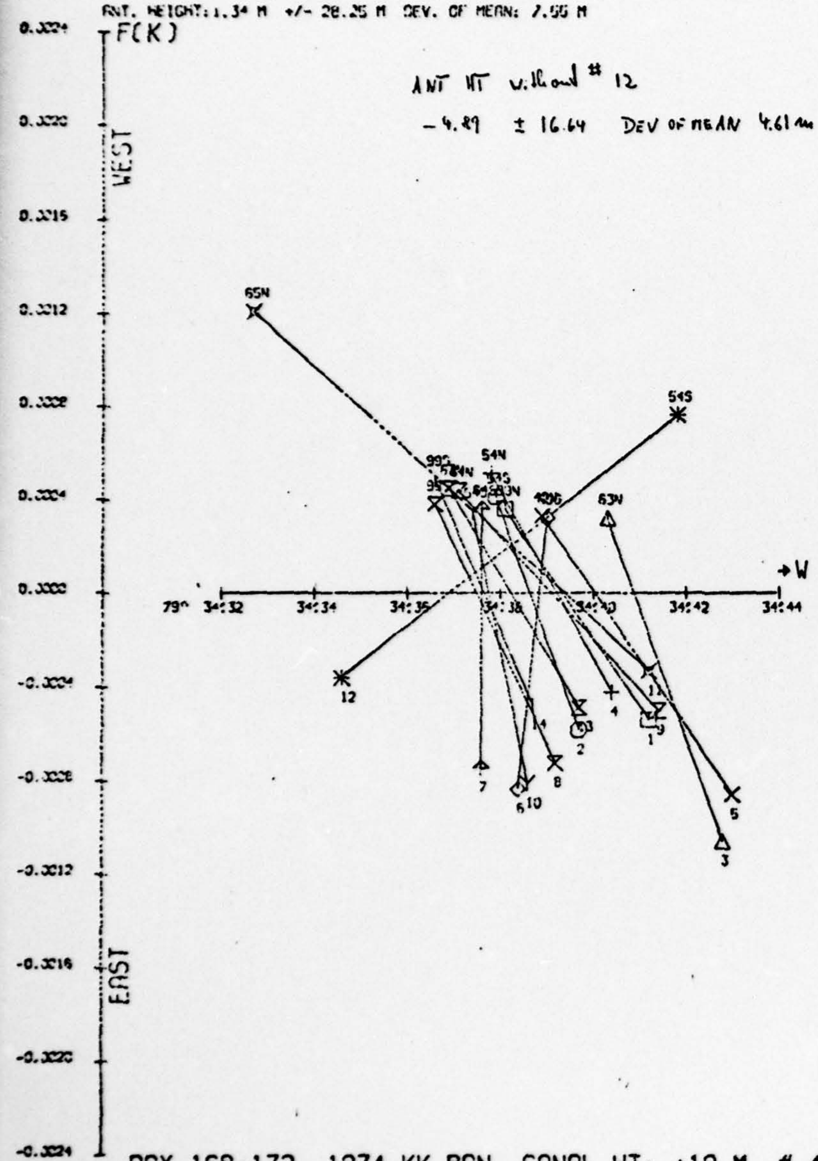
LAT.: -2° 16:8055 +/- 0:2553 (473.05 M) DEV. OF MEAN: 0:1805 (334.50 M)
LONG.: 79° 54:5162
ANT. HEIGHT: 135.94 M



DAY 50-51 1973 KK GUAYAQUIL HT: +28 M # 32 DC>8 (3σ)

156

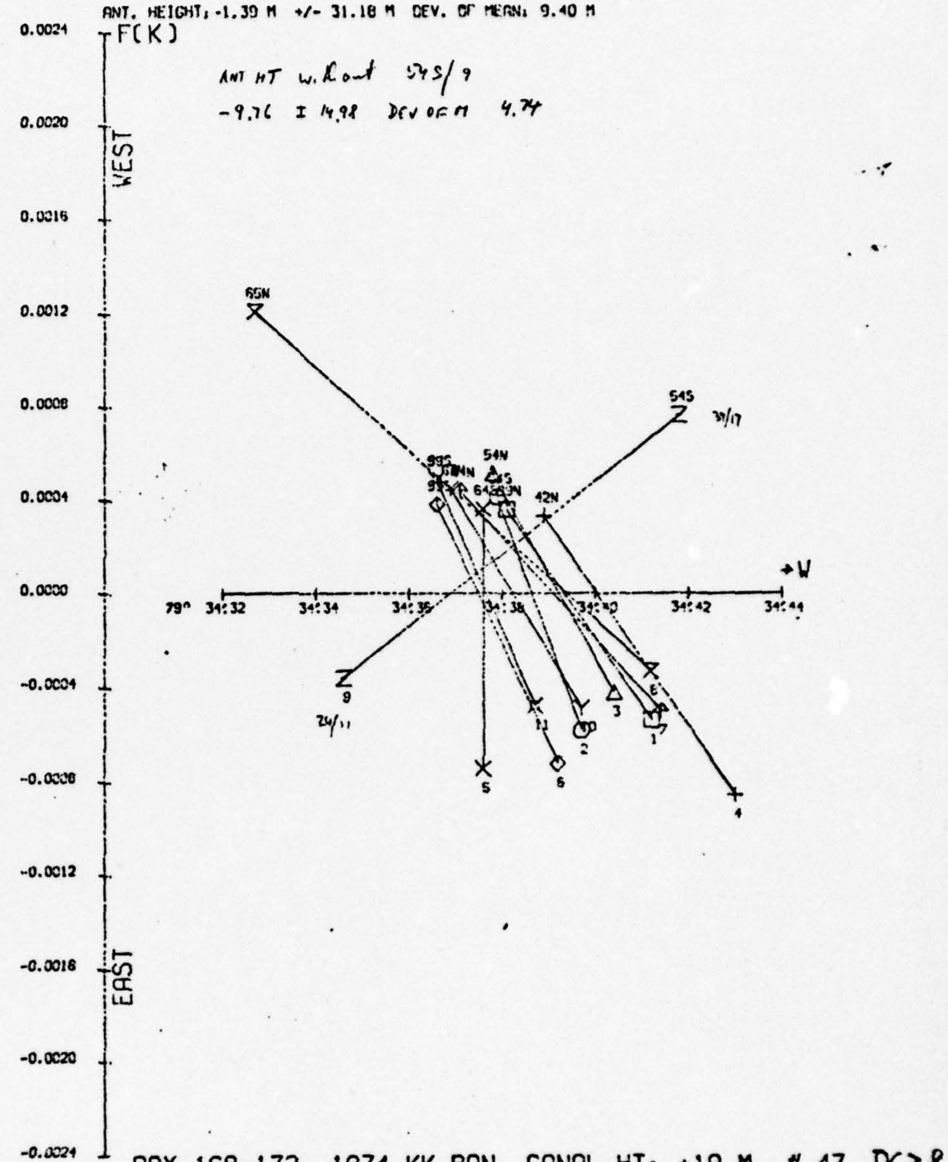
LAT.: 8° 57:1079 +/- 0:0381 (70.56 M) DEV. OF MEAN: 0:0072 (13.35 M)
LONG.. 79° 34:3855 +/- 0:0111 (20.26 M) 0:0030 (5.41 M)
ANT. HEIGHT: 1.34 M +/- 28.25 M DEV. OF MEAN: 7.55 M



DAY 168-172 1974 KK PAN. CANAL HT: +19 M # 47 DC>5 (3σ)

171

LAT.: 8° 57:1116 +/- 0:0208 (38.61 M) DEV. OF MEAN: 0:0044 (8.23 M)
LONG.. 79° 34:3051 +/- 0:0100 (18.22 M) 0:0030 (5.49 M)
ANT. HEIGHT: -1.39 M +/- 31.18 M DEV. OF MEAN: 9.40 M

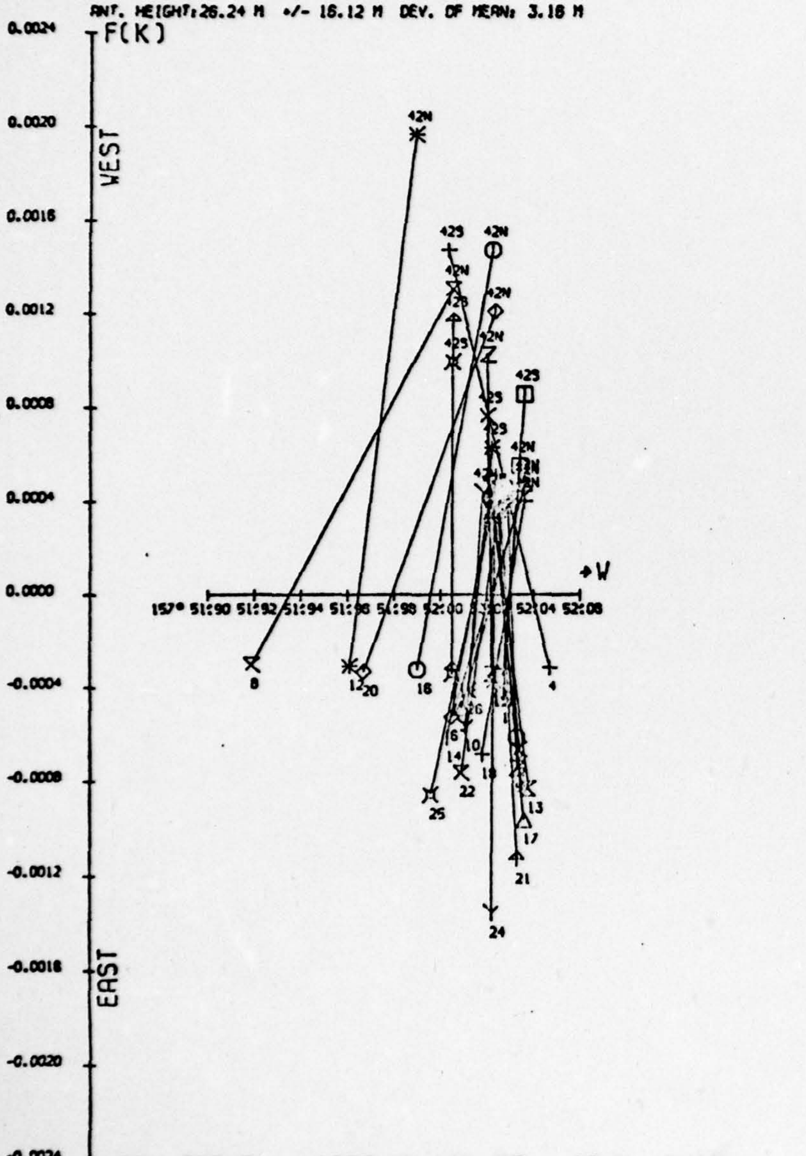


DAY 168-172 1974 KK PAN. CANAL HT: +19 M # 47 DC>8 (3σ)

Group IV

SEP 21 1976

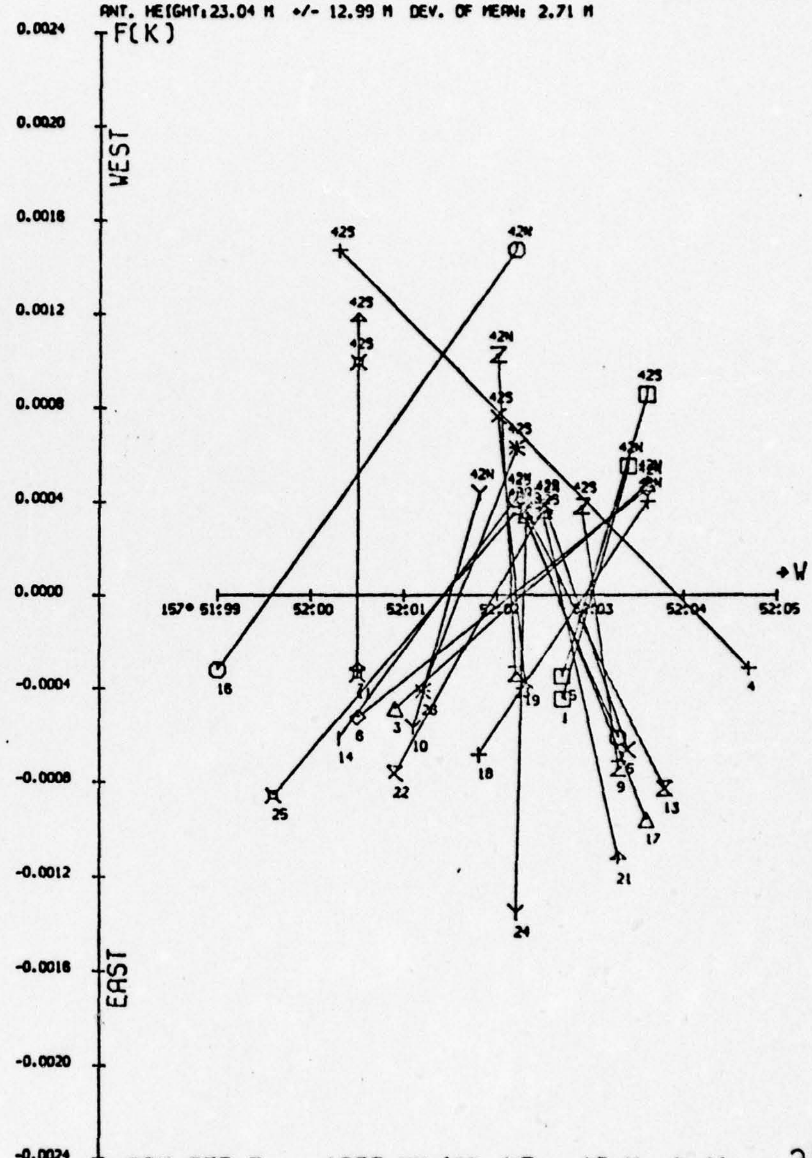
LAT.: 21° 18:8042 +/- 0:0282 (48.54 M) DEV. OF MEAN: 0:0036 (6.73 M)
LONG.: 157° 52:0141 +/- 0:0230 (39.72 M) 0:0045 (7.79 M)
ANT. HEIGHT: 26.24 M +/- 16.12 M DEV. OF MEAN: 3.18 M



DAY 353-7 1973 KK HNL HT: +19 M # 41

SEP 21 1976

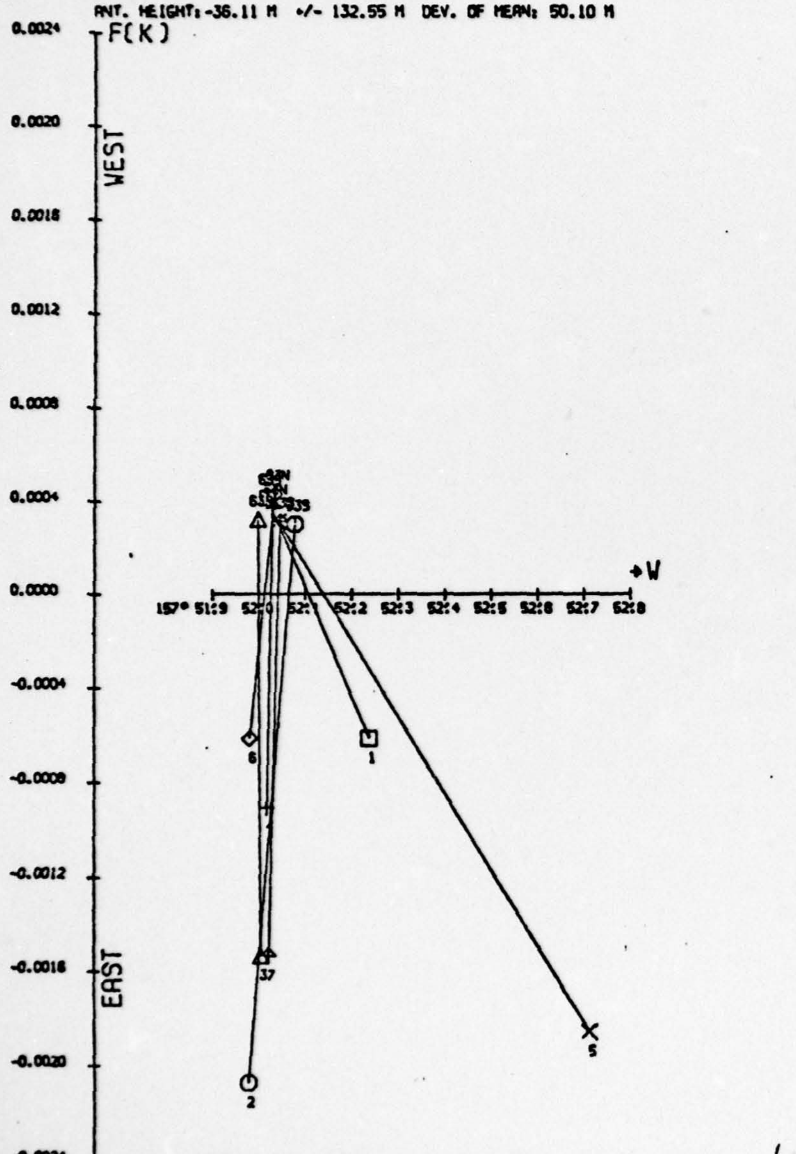
LAT.: 21° 18:8091 +/- 0:0208 (38.49 M) DEV. OF MEAN: 0:0031 (5.68 M)
LONG.: 157° 52:0213 +/- 0:0099 (17.08 M) 0:0021 (3.56 M)
ANT. HEIGHT: 23.04 M +/- 12.99 M DEV. OF MEAN: 2.71 M



DAY 353-7 1973 KK HNL HT: +19 M # 41

SEP 21 1976

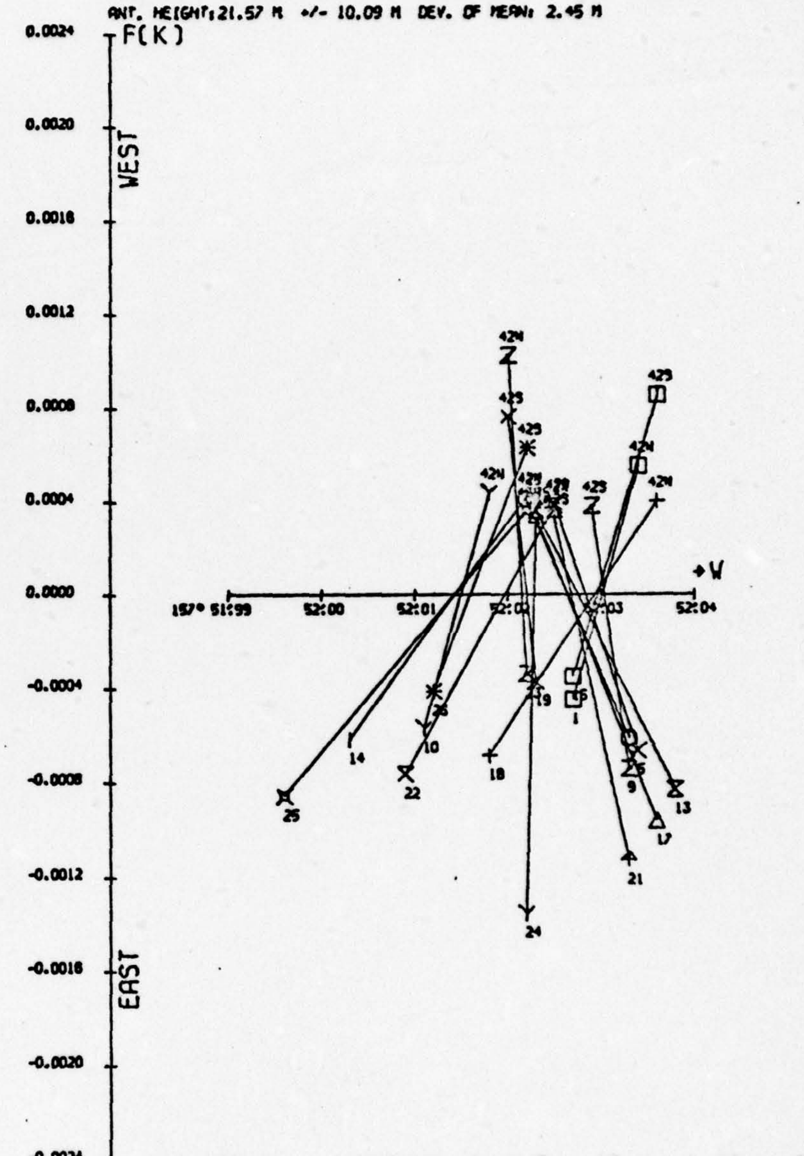
LAT.: 21° 18:8184 +/- 0:0365 (87.58 M) DEV. OF MEAN: 0:0097 (18.08 M)
LONG.: 157° 52:0554 +/- 0:0512 (88.38 M) 0:0193 (33.40 M)
ANT. HEIGHT: -36.11 M +/- 132.55 M DEV. OF MEAN: 50.10 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 (36)(26)

SEP 21 1976

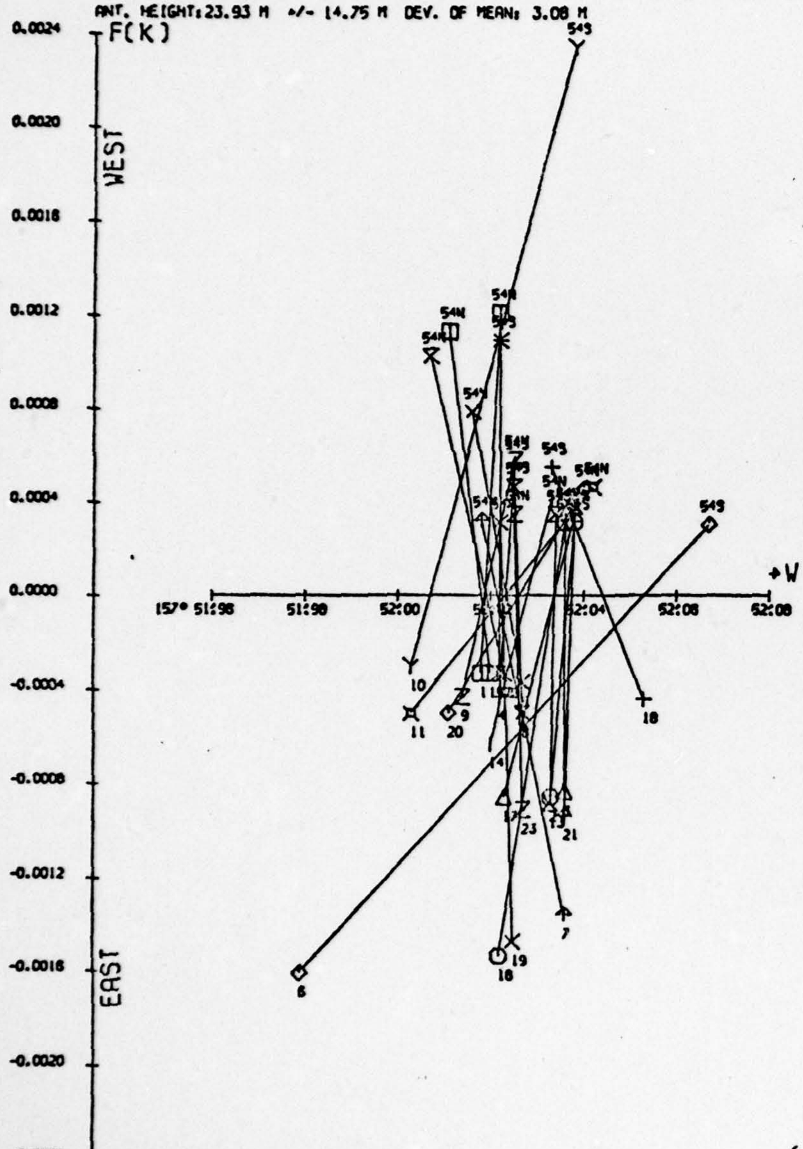
LAT.: 21° 18:8103 +/- 0:0208 (38.58 M) DEV. OF MEAN: 0:0036 (6.61 M)
LONG.: 157° 52:0235 +/- 0:0059 (10.14 M) 0:0014 (2.46 M)
ANT. HEIGHT: 21.57 M +/- 10.09 M DEV. OF MEAN: 2.45 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 26

SEP 21 1976

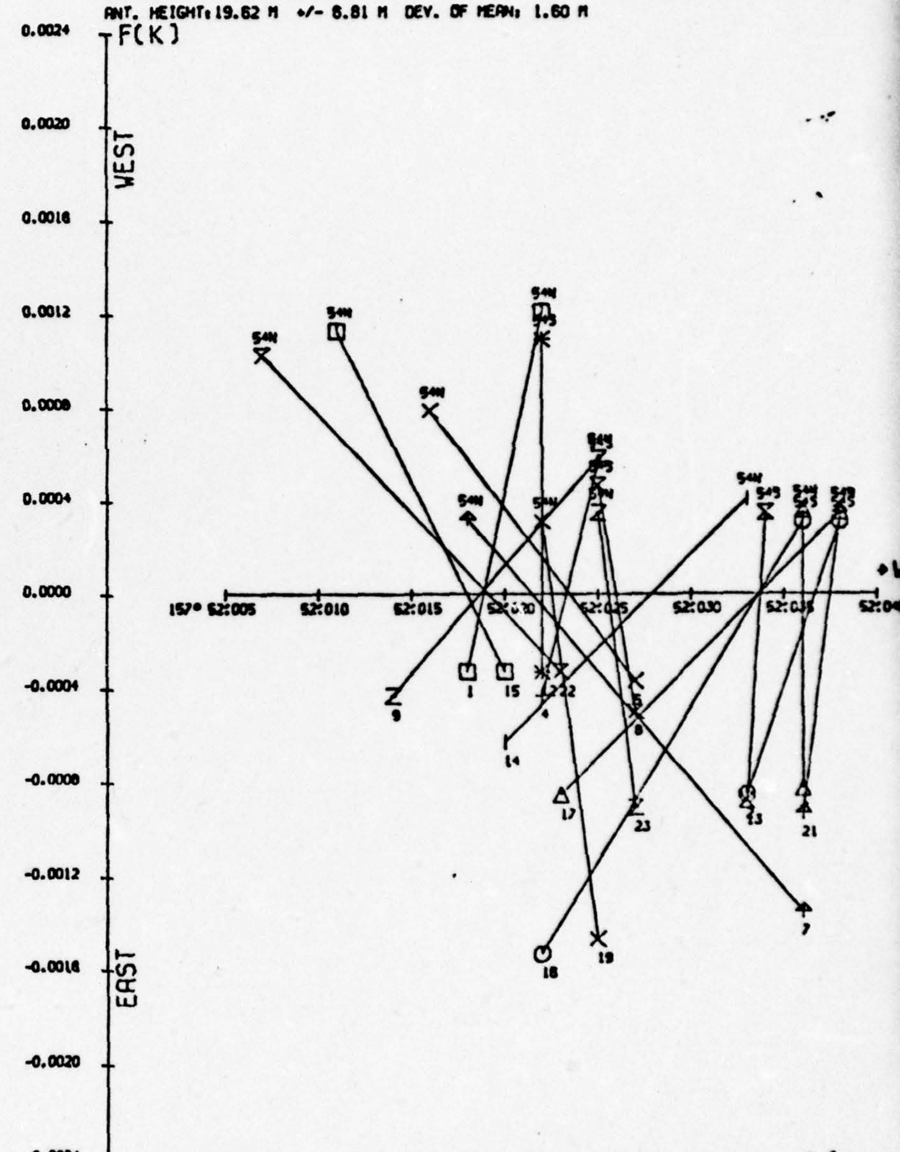
LAT.: 21° 18:8005 +/- 0:0303 (58.18 M) DEV. OF MEAN: 0:0045 (8.28 M)
LONG.: 157° 52:0274 +/- 0:0100 (17.20 M) 0:0021 (3.59 M)
ANT. HEIGHT: 23.93 M +/- 14.75 M DEV. OF MEAN: 3.08 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 (35)

SEP 21 1976

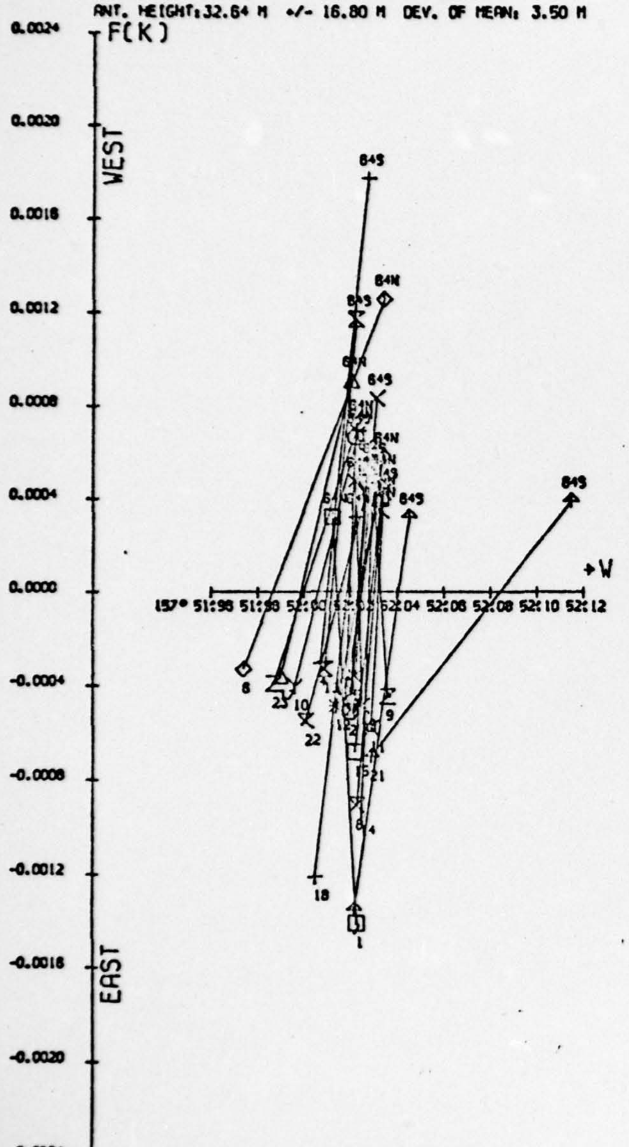
LAT.: 21° 18:8035 +/- 0:0288 (53.05 M) DEV. OF MEAN: 0:0048 (8.84 M)
LONG.: 157° 52:0285 +/- 0:0069 (11.85 M) 0:0016 (2.79 M)
ANT. HEIGHT: 19.62 M +/- 6.81 M DEV. OF MEAN: 1.60 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 25

SEP 21 1976

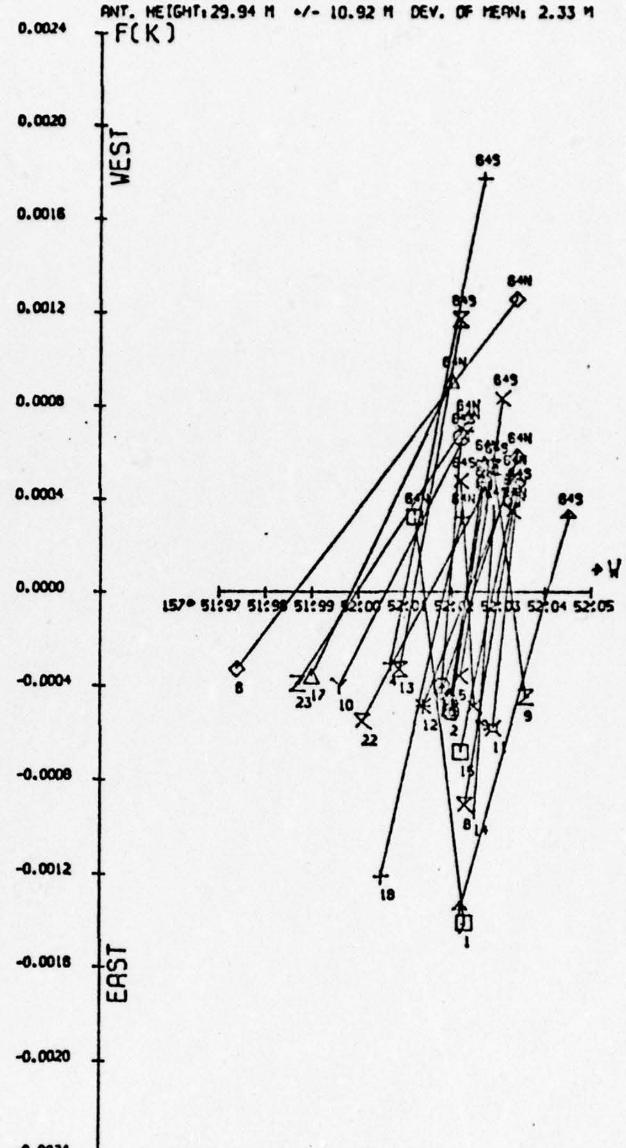
LAT.: 21° 18:8037 +/- 0:0239 (44.20 M) DEV. OF MEAN: 0:0035 (6.52 M)
LONG.: 157° 52:0217 +/- 0:0185 (31.98 M) 0:0039 (6.87 M)
ANT. HEIGHT: 32.64 M +/- 16.80 M DEV. OF MEAN: 3.50 M



DAY 353-7 1973 KK HNL HT: +19 M # 41

SEP 21 1976

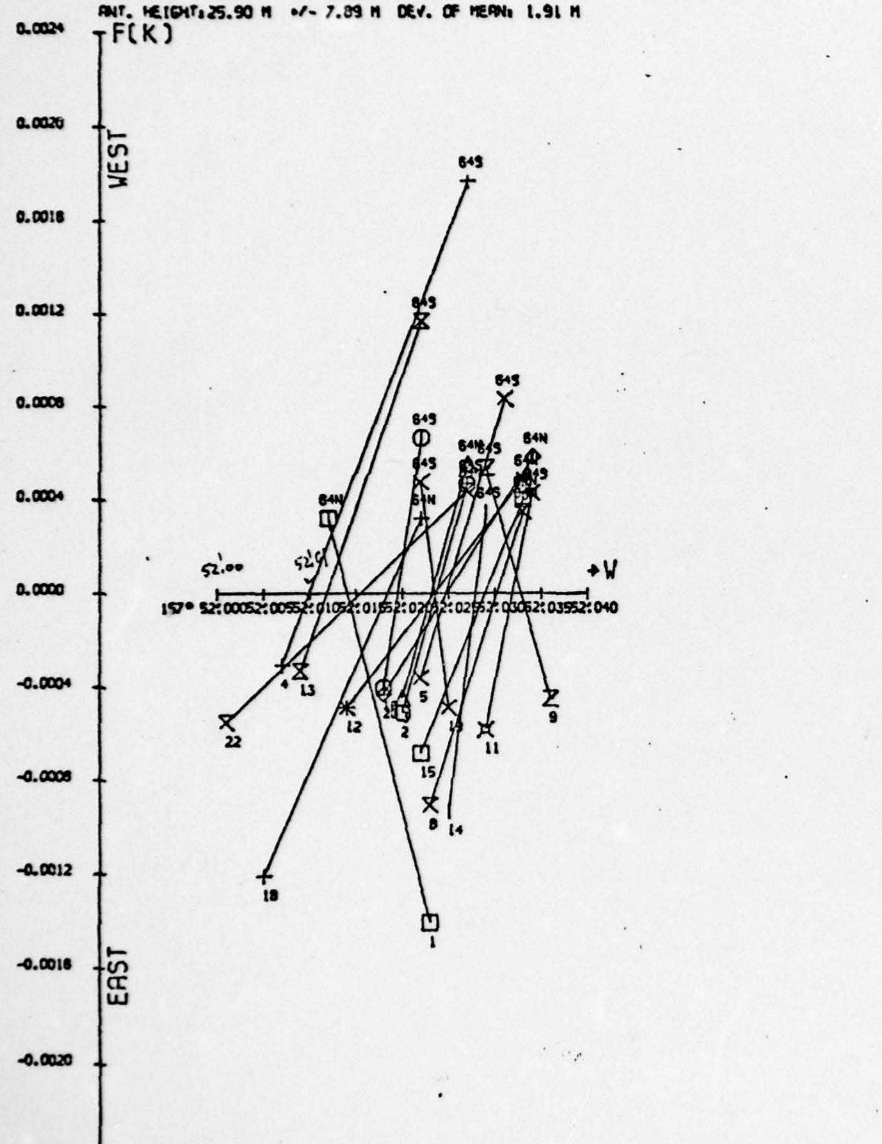
LAT.: 21° 18:8025 +/- 0:0232 (42.99 M) DEV. OF MEAN: 0:0035 (6.48 M)
LONG.: 157° 52:0188 +/- 0:0128 (22.18 M) 0:0027 (4.73 M)
ANT. HEIGHT: 29.94 M +/- 10.92 M DEV. OF MEAN: 2.33 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 36

P 21 1976

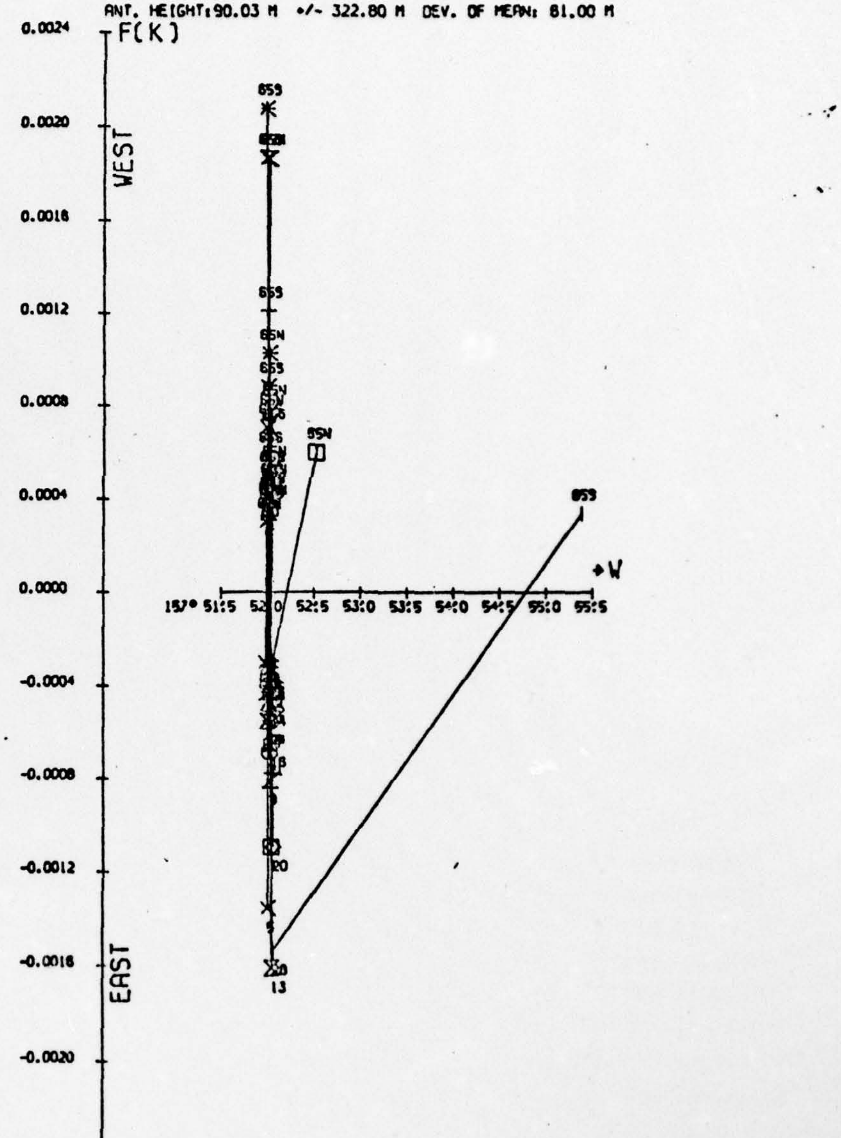
LAT.: 21° 18:8081 +/- 0:0225 (41.88 M) DEV. OF MEAN: 0:0039 (7.15 M)
LONG.: 157° 52:0228 +/- 0:0069 (11.87 M) 0:0017 (2.88 M)
ANT. HEIGHT:25.90 M +/- 7.89 M DEV. OF MEAN: 1.91 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 26

SEP 21 1976

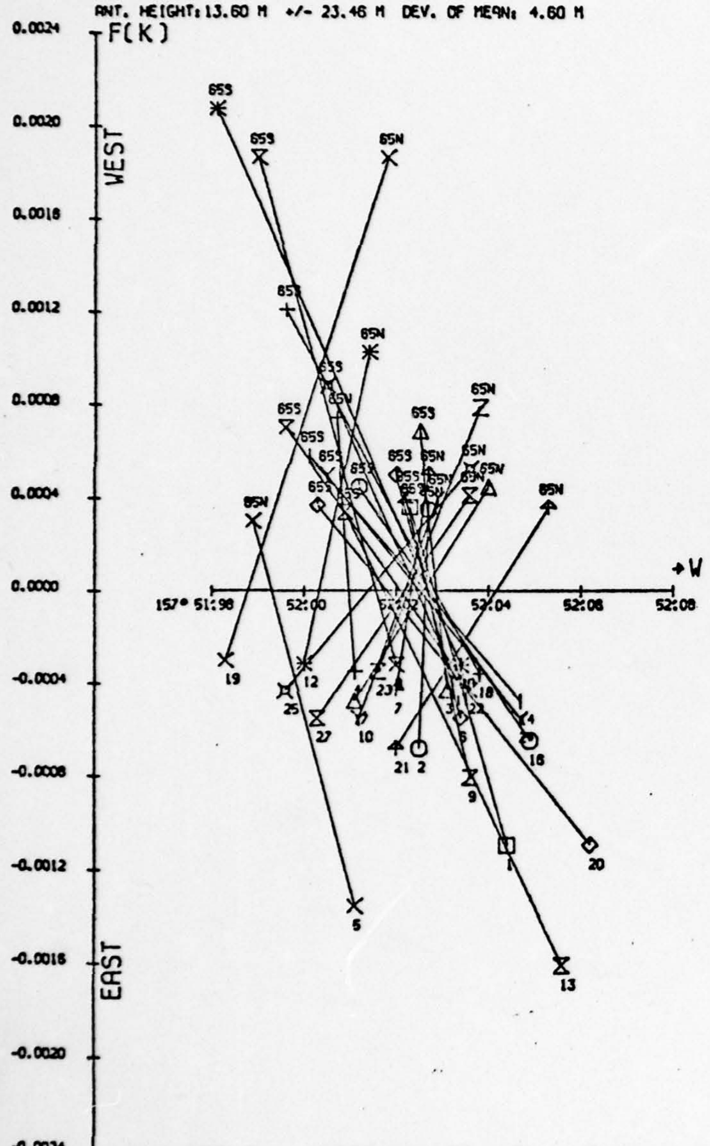
LAT.: 21° 18:8923 +/- 0:6480 (1197.24 M) DEV. OF MEAN: 0:0863 (159.99 M)
LONG.: 157° 52:1257 +/- 0:5218 (900.87 M) 0:0986 (170.25 M)
ANT. HEIGHT:90.03 M +/- 322.80 M DEV. OF MEAN: 81.00 M



DAY 353-7 1973 KK HNL HT: +19 M # 41

P 21 1976

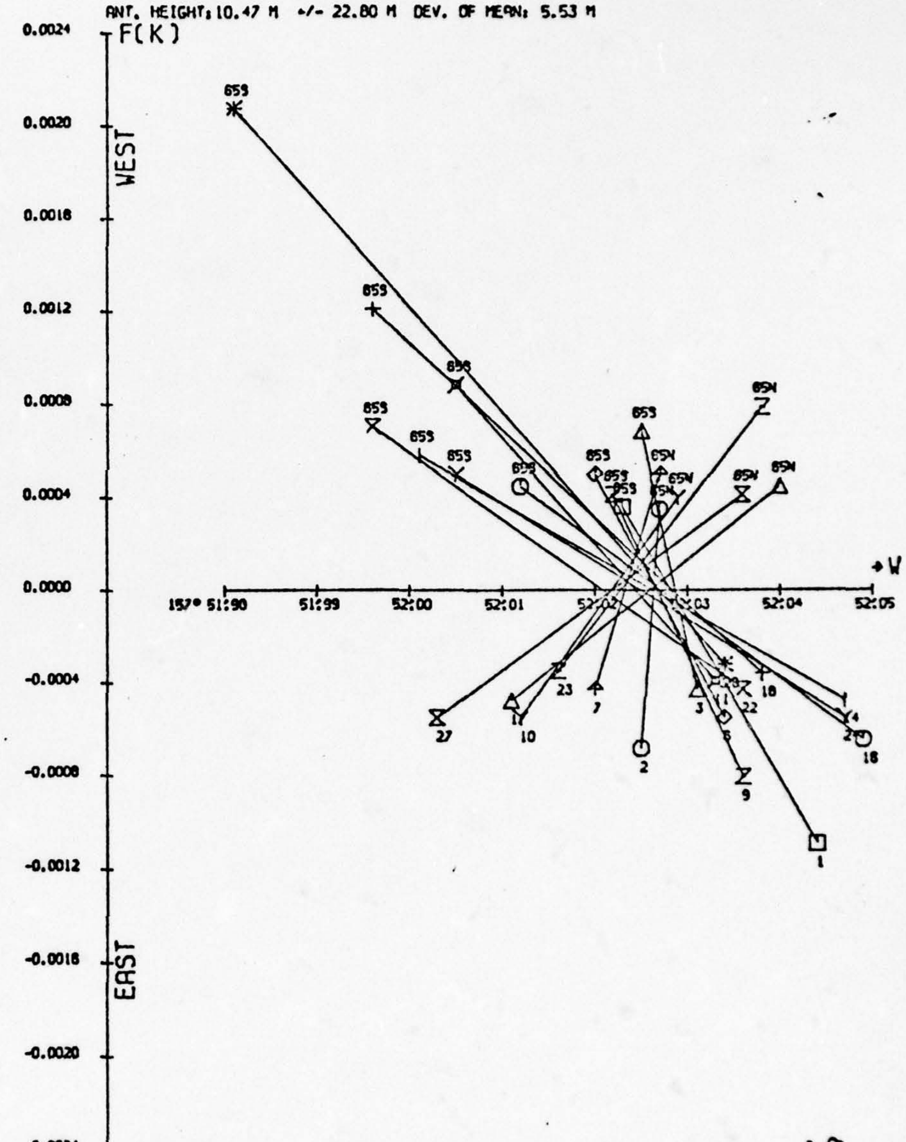
LAT.: 21° 18:8083 +/- 0:0252 (46.82 M) DEV. OF MEAN: 0:0035 (6.46 M)
LONG.: 157° 52:0204 +/- 0:0114 (19.72 M) 0:0022 (3.87 M)
ANT. HEIGHT: 13.60 M +/- 23.46 M DEV. OF MEAN: 4.60 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 36

SEP 21 1976

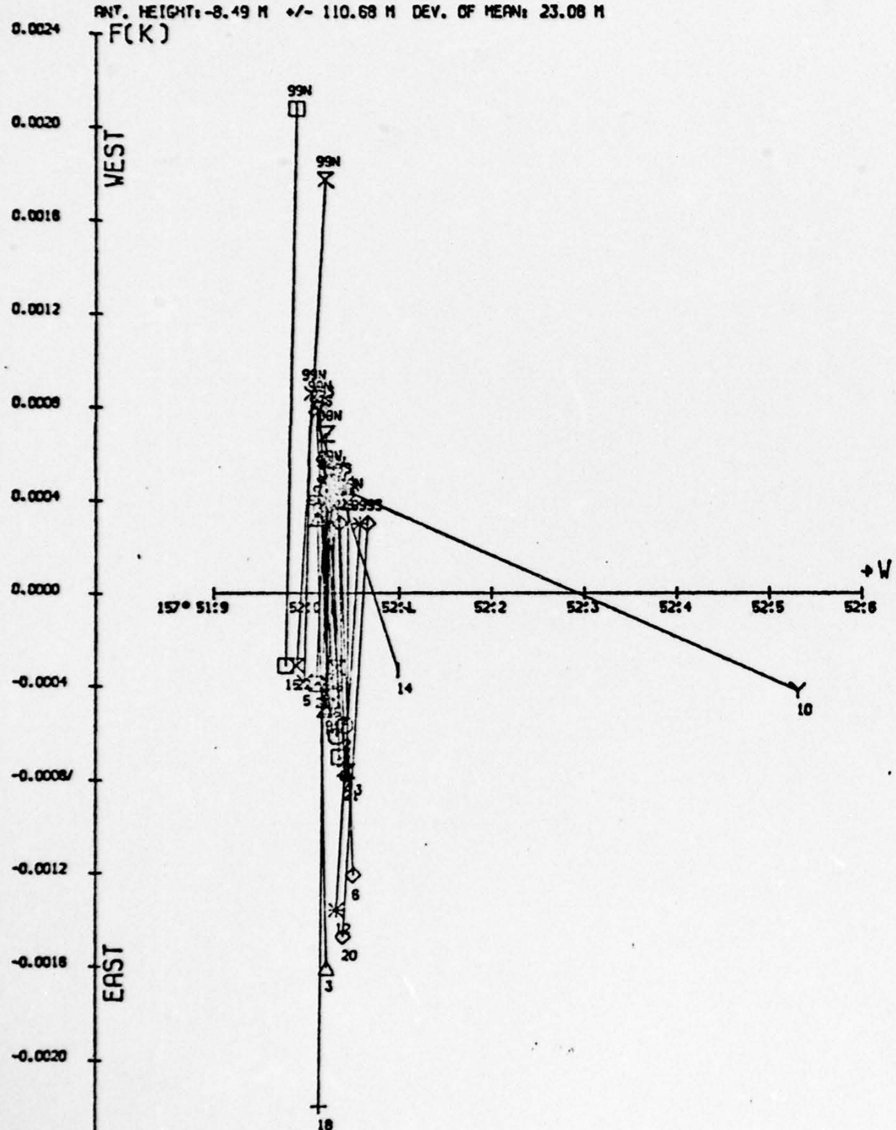
LAT.: 21° 18:8098 +/- 0:0241 (44.58 M) DEV. OF MEAN: 0:0041 (7.85 M)
LONG.: 157° 52:0253 +/- 0:0025 (4.25 M) 0:0006 (1.03 M)
ANT. HEIGHT: 10.47 M +/- 22.80 M DEV. OF MEAN: 5.53 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 26

SEP 21 1976

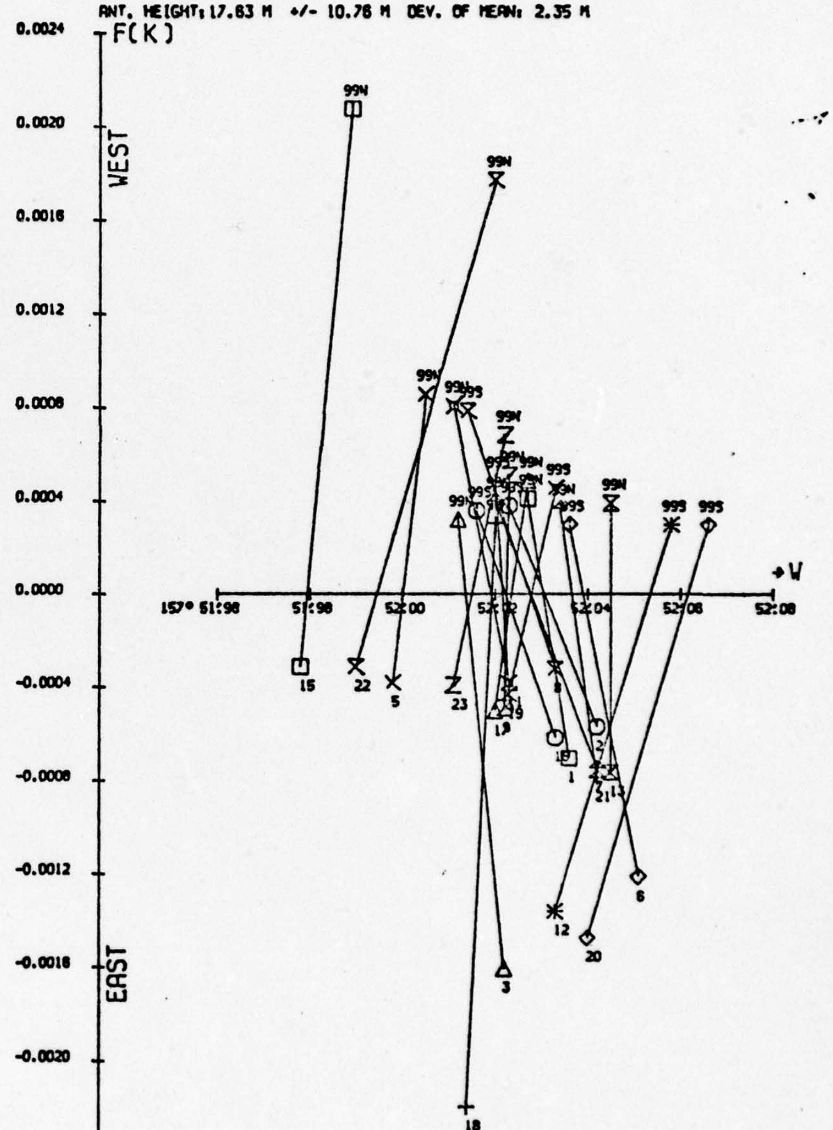
LAT.: 21° 18:7781 +/- 0:0819 (114.83 M) DEV. OF MEAN: 0:0091 (16.90 M)
LONG.: 157° 52:0380 +/- 0:0590 (101.93 M) 0:0123 (21.25 M)
ANT. HEIGHT: -8.49 M +/- 110.68 M DEV. OF MEAN: 23.08 M



DAY 353-7 1973 KK HNL HT: +19 M # 41

SEP 21 1976

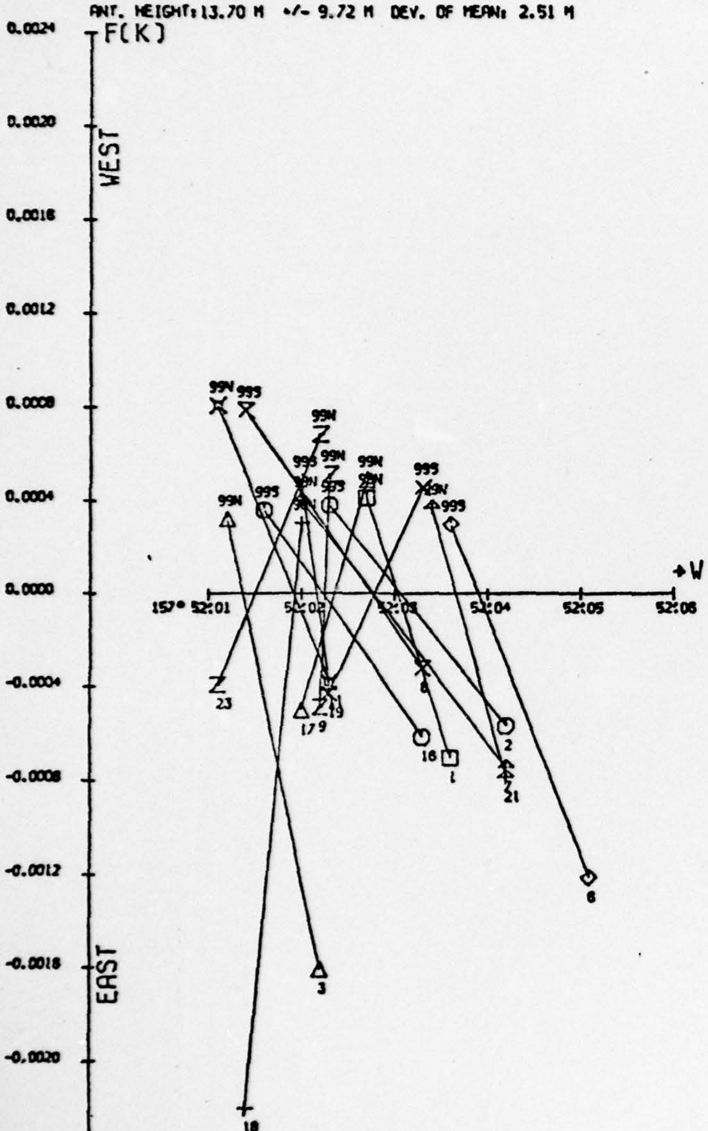
LAT.: 21° 18:7747 +/- 0:0813 (113.58 M) DEV. OF MEAN: 0:0095 (17.53 M)
LONG.: 157° 52:0243 +/- 0:0188 (32.08 M) 0:0041 (7.00 M)
ANT. HEIGHT: 17.83 M +/- 10.78 M DEV. OF MEAN: 2.35 M



DAY 353-7 1973 KK HNL HT: +19 M # 41

SEP ~~21~~ 1976 SEP 21 1976

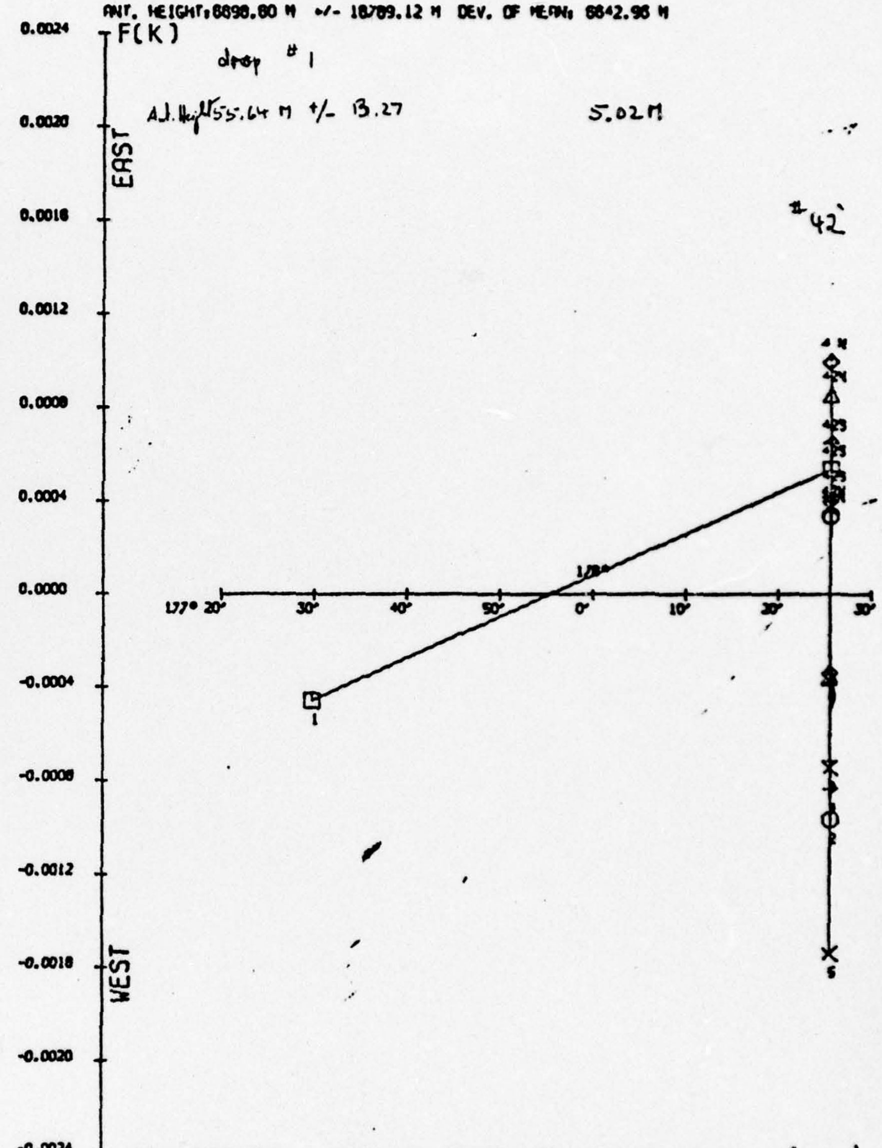
LAT.: 21° 18:7861 +/- 0:0325 (80.15 M) DEV. OF MEAN: 0:0059 (10.98 M)
LONG.: 157° 52:0251 +/- 0:0072 (12.49 M) 0:0019 (3.23 M)
ANT. HEIGHT: 13.70 M +/- 9.72 M DEV. OF MEAN: 2.51 M



DAY 353-7 1973 KK HNL HT: +19 M # 41 25

SEP 22 1976

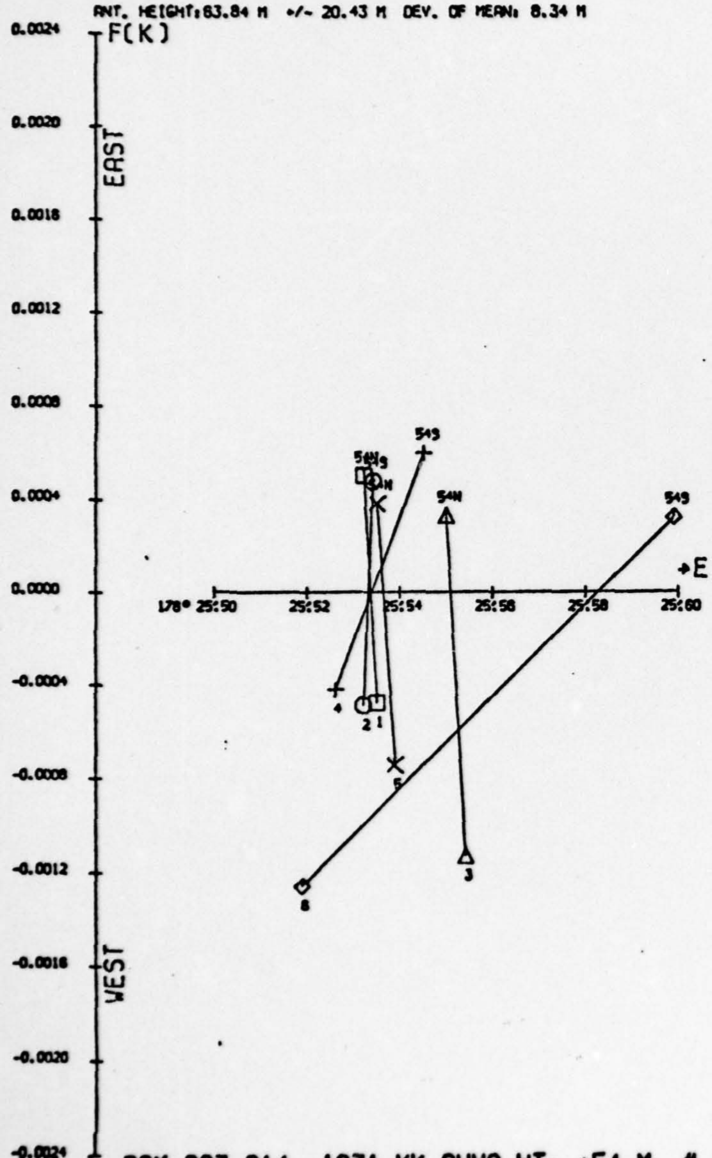
LAT.: -18° 9:8604 +/- 7:4982 (13892.01 M) DEV. OF MEAN: 1:8741 (3473.00 M)
LONG.: 178° 21:7737 +/- 10:8544 (18781.14 M) 3:7689 (6833.08 M)
ANT. HEIGHT: 6898.80 M +/- 18789.12 M DEV. OF MEAN: 6842.96 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 (36)

EP 22 1976

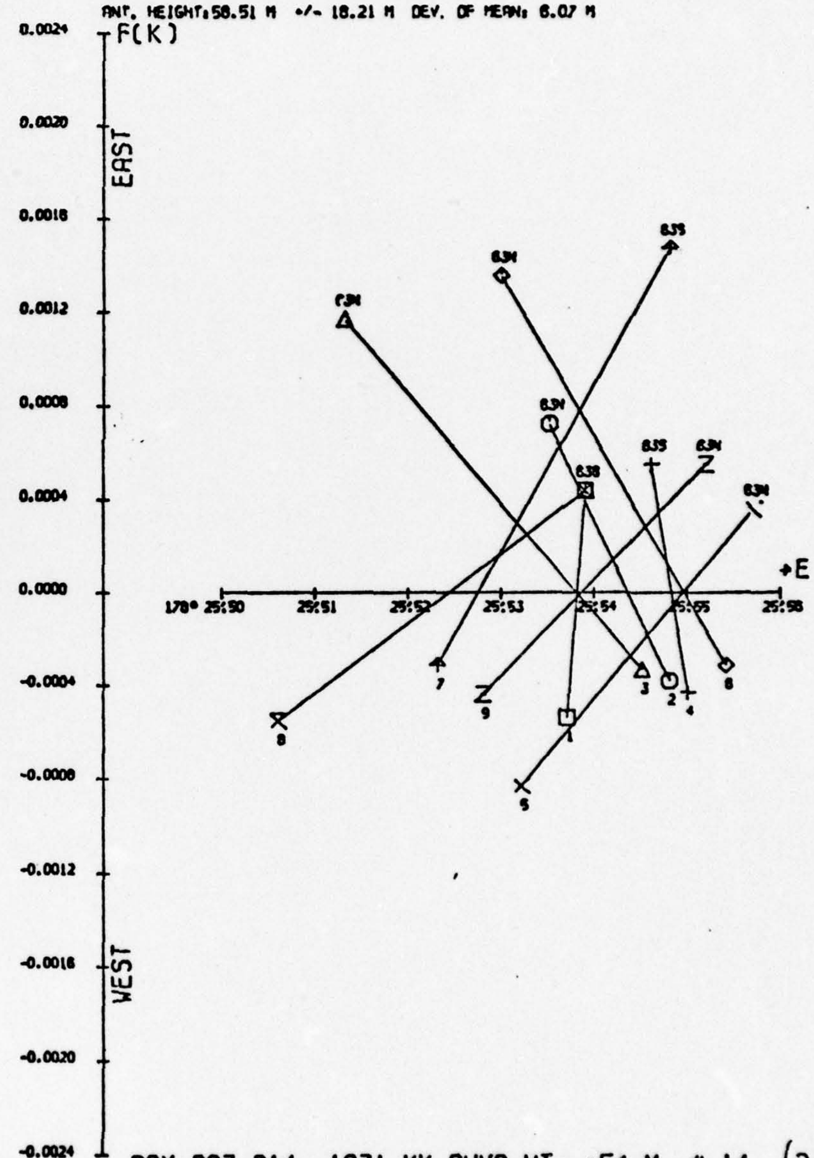
LAT.: -18° 7:7768 +/- 0:0311 (57.84 M) DEV. OF MEAN: 0:0090 (16.64 M)
LONG.: 178° 25:5444 +/- 0:0197 (34.62 M) 0:0080 (14.13 M)
ANT. HEIGHT: 63.84 M +/- 20.43 M DEV. OF MEAN: 8.34 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 (36)

SEP 22 1976

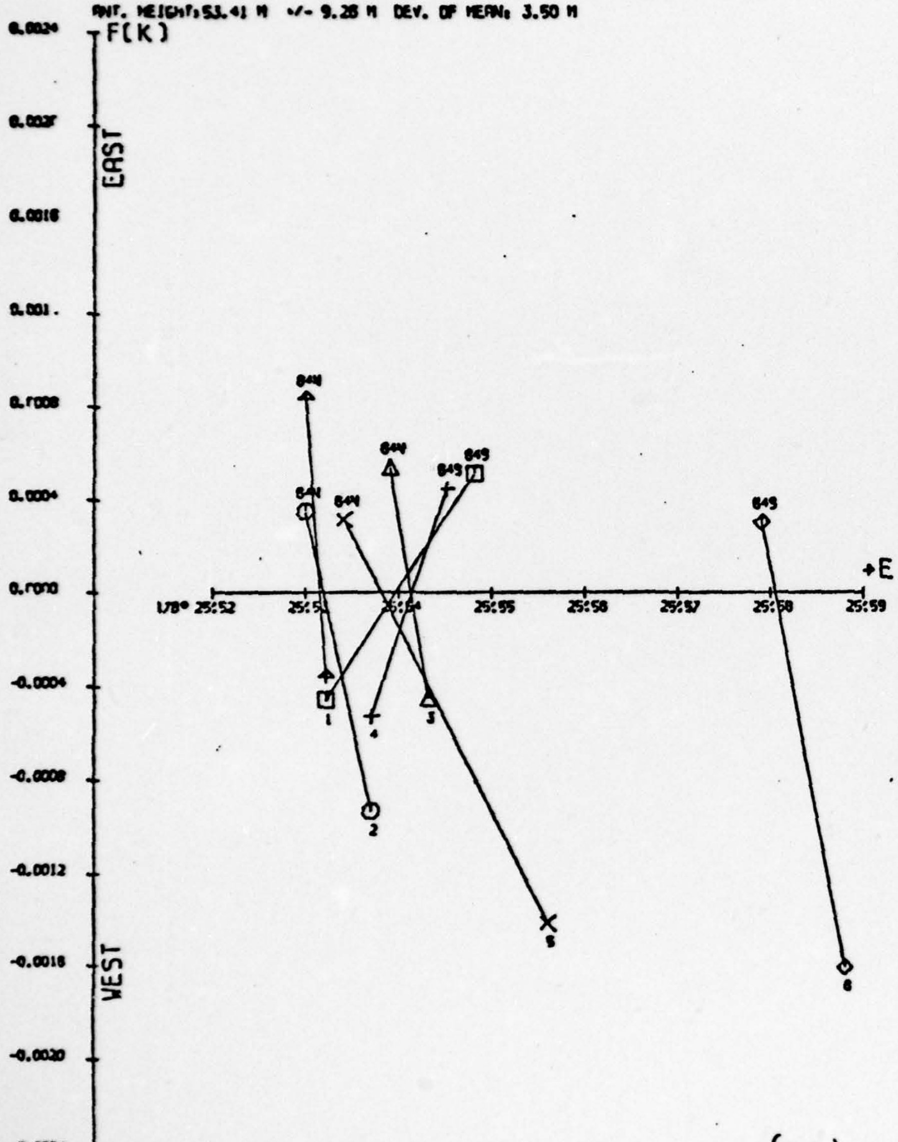
LAT.: -18° 7:7795 +/- 0:0241 (44.59 M) DEV. OF MEAN: 0:0057 (10.51 M)
LONG.: 178° 25:5391 +/- 0:0093 (18.33 M) 0:0031 (5.44 M)
ANT. HEIGHT: 58.51 M +/- 18.21 M DEV. OF MEAN: 6.07 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 (36)

SEP 22 1976

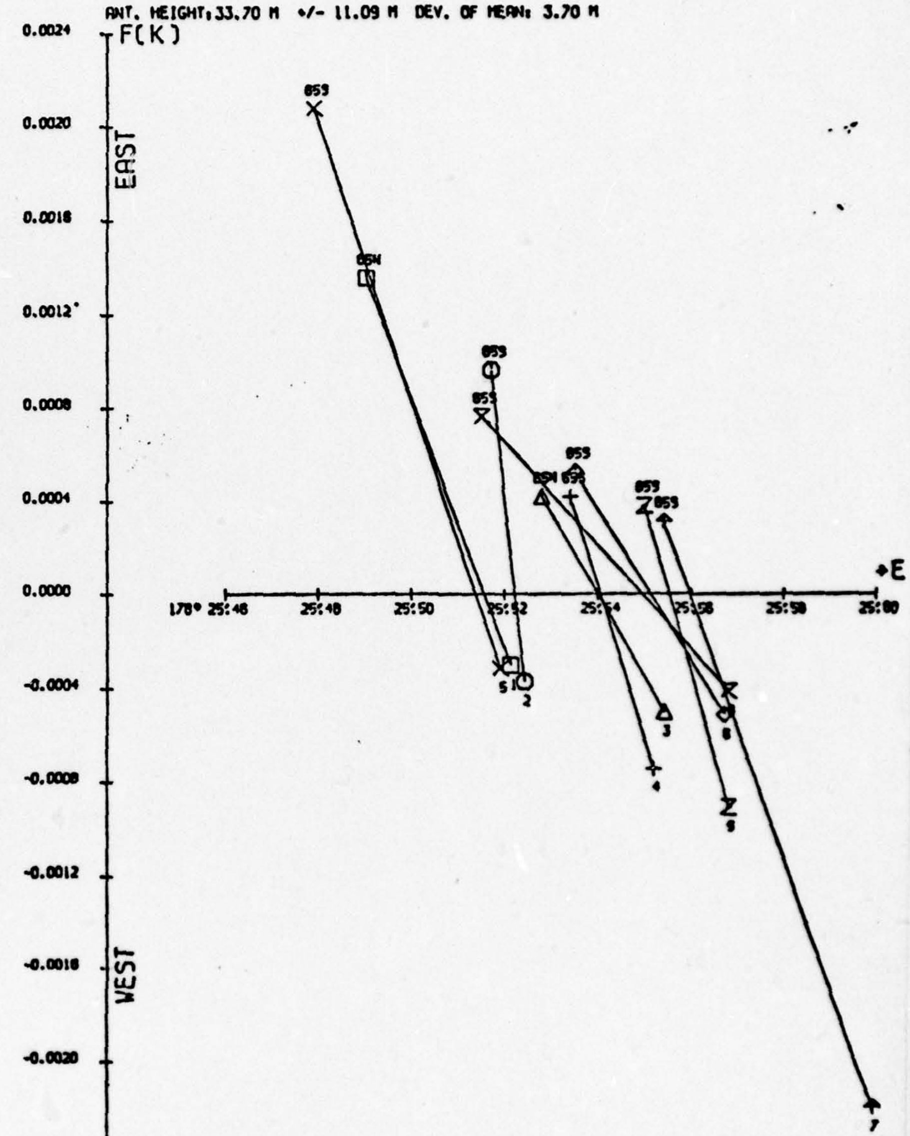
LAT.: -18° 7:7888 +/- 0:0327 (80.53 M) DEV. OF MEAN: 0:0087 (18.18 M)
LONG.: 178° 25:5430 +/- 0:0189 (29.88 M) 0:0084 (11.22 M)
ANT. HEIGHT: 53.41 M +/- 9.28 M DEV. OF MEAN: 3.50 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 (36)

SEP 22 1976

LAT.: -18° 7:7578 +/- 0:0252 (46.70 M) DEV. OF MEAN: 0:0059 (11.01 M)
LONG.: 178° 25:5378 +/- 0:0175 (30.74 M) 0:0058 (10.25 M)
ANT. HEIGHT: 33.70 M +/- 11.09 M DEV. OF MEAN: 3.70 M



DAY 207-214 1971 KK SUVA HT: +54 M # 14 (36)

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Navigational satellites
Longitude, latitude, height
Sea level-geoidal height
Double pass method
Pacific harbors
DSDP sites

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A relatively simple double pass method is used to (a reduce longitudinal spread of satellite navigation fixes and (b) obtain antenna height or sea level height on board a ship in a fixed harbor or dixed open-sea position (over an acoustic beacon). Required are the satellite navigator output of latitude, longitude, elevation angle, and path geometry for two consecutive passes (one east and one west of the site) of the same satellite.

The standard deviation of one such double pass observation in a larger (cont.)

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20. ABSTRACT (cont.)

sigma sub m,

data set is usually below 20 m in both longitude and height. Improvements in the position accuracy of a site (as measured by σ_m, the standard deviation of the mean or the 95% confidence interval) are obtained by restricting observations to passes: with a high number of symmetric Doppler counts, between given elevation angles, with a small number of iterations of the satellite navigator, and with eliminations of double pass results that are outside specified limits (usually 2σ) in height and/or longitude. An accuracy σ_m of 10 m or less is usually achieved with four to five days of recordings.

Sea level height thus determined on board the R.V. Kana Keoki in harbors around the Pacific and on board the Glomar Challenger in position over Deep Sea Drilling Project sites in the Atlantic show good agreement with geoidal height models.

Determining sea level (with respect to the Navigation Satellite Reference) using the double pass method thus provides an important independent alternative to Sky Lab Radar Altimetry for the measurement of geoidal height over the open oceans.